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JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA, INC.

Founded 1913 :: :: Incorporated 1937

Vol. XXX

1943 - 1944

The Authors of Papers are alone responsible for the statements
and
the opinions expressed therein.

Published 11th March, 1946.

Printed for the Society by
ROBERT H. MILLER, Government Printer, Perth.

1946.

L 14133/45

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The Royal Society of Western Australia (Inc.).

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30th JUNE, 1944.

Ladies and Gentlemen,

Your Council begs to submit the following report for the year ending 30th June, 1944.

Council.—Following established custom the Council appointed an Executive Committee to deal with the routine business of the Society, and to submit quarterly reports to the Council.

Four meetings of Council, and six meetings of the Executive were held during the year.

Finance.—There is a credit balance of £174 16s. 11d. in the General Fund; the Endowment Fund amounts to £306 15s. 7d., and the Medal Fund to £9 9s. There are certain heavy commitments outstanding to the Government Printer on account of the publication of Volume XXVIII of the Journal, and further liabilities have been incurred with the printing of Volume XXIX, which is not yet complete.

The cost of publication has greatly increased during the past year, owing to a sharp rise in the price of materials.

Membership.—There has been a slight increase in the total membership of the Society, which now numbers 165, made up as follows:—

Honorary Members	7
Corresponding Members	9
Life Members	2
Ordinary Members	111
Associate Members	30
Student Members	6

The names of seven Ordinary Members were added to the Register during the year; one Associate transferred to full Membership; and one Ordinary Member resigned.

Journal.—Progress has been made in bringing the publication of the Journal up-to-date. During the year two volumes (XXVII and XXVIII) were distributed, and the publication of Volume XXIX is proceeding.

It is proposed in future to publish the Journal in a number of parts, which may vary according to the quantity of matter presented for publication.

This will expedite publication, which is most desirable, particularly for taxonomic papers in the Biological Sciences.

Library.—The number of Institutions with which we have an exchange agreement remains the same as during the two preceding years. One Institution has been forced by the present shortage of paper to restrict its circulation and has, therefore, had to cancel its agreement with this Society. To balance this we have agreed to reserve copies of our Journal for the Netherlands East Indies Library, with a view to an exchange agreement after the war.

E. M. WATSON, President.

A. G. NICHOLLS, K. R. MILES,
Joint Hon. Secretaries.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA, INCORPORATED.

Statement of Receipts and Expenditure for the Year ended 30th June, 1944.

General Fund

Receipts.	£ s. d.	£ s. d.
General Fund—		
Balance at 30th June, 1943	....	225 3 0
Interest on Current Account (S.360) to 31st May, 1944	....	4 13 8
Subscriptions:		
Annual Current and Arrears	106 16 6	
In Advance	5 5 0	
Interest on 1959 War Loan	10 0	
		112 11 6
Government Grant	....	100 0 0
University Grant towards Cost of Publishing Papers 1 and 4, Vol. XXVIII.	....	90 0 0
Sale of back Volumes	....	8 6 9
Authors' extra Reprints	....	4 17 6
Authors' Contributions to Cost of Blocks	....	6 9 0
Duty and Exchange	....	3 5
		£552 4 10

Expenditure.	£ s. d.	£ s. d.
Petty Expenses, Postage, etc.	....	15 16 3
Clerical Assistance	....	3 7 6
Rent—Institution of Engineers	....	30 0 0
Catering for Meetings	....	18 5 0
Government Printer—		
Vol. XXVII.:		
Maps	1 4 6	
Binding, Printing, Report and Index	14 0 7	
		15 5 1
Vol. XXVIII.:		
Nos. 1–7, and 10. Printing	184 10 5	
Blocks	30 6 1	
Index and Binding	33 19 6	
		248 16 0
Miscellaneous Printing	....	11 9 5
Honoraria to Editor—		
Vol. XXVII.	15 15 0	
Vol. XXVIII.	15 15 0	
		31 10 0
Subscription to International Commission on Zoological Nomenclature	....	2 8 8
Cartage	....	10 0
Balance at 30th June, 1944	....	174 16 11
		£552 4 10

Medal Fund

	£ s. d.
Medal Fund—	
Balance at 30th June, 1943	9 5 5
Interest	3 7
	£9 9 0

	£ s. d.
Cash at Bank, Account S361, 30th June, 1944	9 9 0
	£9 9 0

Endowment Fund

	£ s. d.	£ s. d.
Endowment Fund—		
Balance at 30th June, 1943	....	299 0 6
Interest:		
Estimated Interest on War Savings Certificates	6 5 0	
1956 War Loan paid into Account S417	1 6 0	
Account S417	4 1	
		7 15 1
		£306 15 7

	£ s. d.
Balance at 30th June, 1944—	
250 War Savings Certificates at Valuation	225 0 0
1956 War Loan (Interest paid into S417)	40 0 0
1959 War Loan (Interest paid into General Fund, S360, to cover Cost of Two Life Members)	40 0 0
Cash at Bank, Account S417	1 15 7
	£306 15 7

Balance Sheet as at 30th June, 1944.

Liabilities.	£ s. d.	£ s. d.
Subscriptions Paid in Advance		5 5 0
Sundry Creditors—General Fund—		
Government Printer—Vol. XXVIII.	223 5 3	
Miscellaneous	2 1 2	
		225 6 5
Surplus of Assets over Liabilities		455 1 8
		£685 13 1

Assets.	£ s. d.	£ s. d.
Cash at Bank—		
General Fund		174 16 11
Medal Fund		9 9 0
Endowment Fund		1 15 7
Subscriptions in Arrears		10 0 0
Investments—		
War Savings Certificates at Valuation	225 0 0	
1956 War Loan	40 0 0	
1959 War Loan	40 0 0	
		305 0 0
Library Shelving at Cost		90 19 11
Sundry Debtors—General Fund—		
Reprints and Blocks. Vols. XXV. and XXVI.	2 9 5	
Reprints and Blocks, Vol. XXVIII.	91 2 3	
		93 11 8
		£685 13 1

Audited and found in agreement with books, receipts and vouchers produced.

J. SHEARER, Hon. Treasurer,
1st July, 1944.

We consider this to be a true statement of the Royal Society's Accounts.

C. TEICHERT,
D. CARROLL,
Hon. Auditors.
2nd July, 1944.

ABSTRACT OF PROCEEDINGS, 1943-1944.

13TH JULY, 1943—

Annual General Meeting in Gledden Hall. Presidential Address: "The Collie Coalfield, its Problems and its Economic Importance," by Mr. R. C. Wilson.

10TH AUGUST, 1943—

Paper—"The Deterioration of Jute Materials in contact with Superphosphate and Mixtures containing Superphosphate," by Dr. L. J. H. Teakle and Mr. H. E. Hill.

Address—"Some Drug-yielding Plants of Western Australia," by Mr. C. A. Gardner.

Election of Members—Messrs. T. H. Wilson, L. P. Burgess, and K. C. B. Green (transfer from Associate Member) as Ordinary Members.

Exhibits—Mr. Steedman: Various botanical specimens.

14TH SEPTEMBER, 1943—

Paper—"Fossil Mammals of Western Australia," by Mr. L. Glauert.

Address—"Manufacture of Precision Lenses and their Assemblage in Binoculars," by Mr. C. A. Ramm.

Exhibits—Mr. Steedman: Various botanical specimens.

12TH OCTOBER, 1943—

Addresses—(1) "The History of the Barometer and its Use as a Weather-Glass," by Professor A. D. Ross.

(2) "Modern Developments in Meteorology and Weather-Forecasting," by F/Lt. J. Hogan.

Exhibits—Mr. Glauert: A moth and several caterpillars belonging to the family *Cyclotornidæ* and found in association ants.

Mr. Steedman: Various botanical specimens.

9TH NOVEMBER, 1943—

Addresses—(1) "Some Aspects of Food Rationing in Australia and other Countries," by Dr. E. J. Underwood.

(2) "Recent Investigation in the Greenbushes Tinfield," by Dr. K. R. Miles and Mr. R. S. Matheson.

Election of Member—Mr. G. B. Everard as an Ordinary Member.

Exhibits—Mr. Steedman: Various botanical specimens.

14TH DECEMBER, 1943—

Exhibits—(1) Dr. D. L. Serventy: "Some Fisheries Products." These included examples of Western Australian Canned Fish and specimens of the sea-weed *Eucheuma speciosum* from which local agar agar is being prepared.

(2) Dr. E. M. Watson: "Some Light Alloys." The properties of the principal light metals were described and some castings prepared from various alloys were shown.

(3) Dr. Dorothy Caroll: "Some Minerals of the Light Alloys." Specimens of various Western Australian ores used in the preparation of light alloys were shown, these included bauxite. beryl, magnesite and petlite.

(4) Mr. C. F. H. Jenkins: "The Orange Piercing Moth" (*Othreis materna*). The habits of this pest were outlined and specimens and lantern slides were exhibited, illustrating various stages of the insect's life history.

(5) Mr. L. Glauert: "Some Ants' Guests." The peculiar habits of certain inquilines in ant nests were outlined and various specimens exhibited.

(6) Mr. R. C. Wilson: Some fossil plants remains from the Griffin Colliery, Collie.

(7) Dr. C. Teichert: Some fossil bones, attributable to two groups of reptiles—the *Plesiosaurs* and the *Ichthyosaurs*, collected by Mr. R. S. Matherson in phosphate rock at Dandaragan.

(8) Mr. Steedman: Various botanical specimens.

14TH MARCH, 1944—

Papers—(1) "A Revision of Western Australian Species of *Triodia* R. Br.," by Miss Nancy T. Burbidge.

(2) "New Crustacea from the Swan River Estuary," by Mr. J. M. Thomson.

(3) "The Fauna of the Algal Zone of the Swan River Estuary," by Mr. J. M. Thomson.

Address—"Sharks of Western Australia," by Mr. G. P. Whitley.

11TH APRIL, 1944—

Addresses—(1) "Quartz," by Dr. Dorothy Carroll.

(2) "Plant Breeding for Quality with special reference to Wheat," by Mr. A. J. Milligan and Dr. L. W. Samuel.

9TH MAY, 1944—

Paper—"Investigation of Some Phosphatic Nodules from Dandaragan, Western Australia," by Dr. K. R. Miles.

Addresses—(1) "Mica," by Messrs. R. S. Matheson and J. S. Foxall.

(2) "Principles of Measuring and Controlling Furnace Temperatures," by Mr. J. Shearer.

Election of Member—Sq/Ldr. J. J. Hogan as an Ordinary Member.

Exhibits—Mr. Steedman: Various botanical exhibits.

13TH JUNE, 1944—

Addresses—(1) "Tin," by Mr. R. A. Hobson.

(2) "Crystals," by Dr. R. T. Prider.

(3) "Graphite, and its Recovery in Western Australia," by Dr. E. M. Watson.

Exhibits—(1) Mr. Glauert: A speciment of the Kangaroo Mouse from the Murchison District, and a Black Shouldered Kite which commonly preys on this animal.

(2) Mr. Steedman: Various botanical specimens.

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXX.

1.—THE DETERIORATION OF JUTE MATERIALS IN CONTACT WITH SUPERPHOSPHATE AND MIXTURES CONTAINING SUPERPHOSPHATE.

By

L. J. H. TEAKLE* and H. E. HILL†.

Read 10th August, 1943.

INTRODUCTION.

Superphosphate is now one of the most important of the world's artificial fertilisers and the annual pre-war consumption amounted to nearly 15,000,000 tons. It is commonly marketed in jute containers. These suffer some damage in contact with the superphosphate and considerable economic loss and inconvenience are sometimes incurred.

The protection of jute bags used for the transport of superphosphate has received a great deal of attention in the past, particularly by manufacturers, and the value of many treatments has been tested under field conditions. Unfortunately, the great majority of the tests have led to inconclusive results and there appears to be little standardisation—at least in Australia—of practices designed to lengthen the serviceable life of bags used for superphosphate. Pre-treatment of bags with suitable chemicals is reported to be routine practice in many factories in some countries, but in Western Australia the use of high grade Nauru and Ocean Island rocks in the past has rendered any action unnecessary as a general rule. Every season some complaints of severe damage have been received, but these are not numerous and are confined to parcels railed in the very hottest weather.

During the summer period of 1941/42 when a proportion of rock phosphate from the Egyptian ports of Kosseir and Sofaga was used in the manufacture of superphosphate, many complaints were received regarding the damage to superphosphate bags and railway tarpaulins. The complaints were so general that it was apparent that some new factor had arisen and would need to be controlled for adequate protection of bags and tarpaulins used in the despatch of superphosphate made from Egyptian rock.

Attempts had been made, before the introduction of Egyptian phosphate, to devise protective treatments. In 1919 the Agricultural Department recommended that empty bags on farms should be dipped in milk of

*Plant Nutrition Officer, Department of Agriculture.

† Supervising Chemist, Government Chemical Laboratory.

lime and then dried before storing for future use. Manufacturers, also, had tried out a variety of treatments, including—

(a) *Dipping.*

Bags were dipped in sodium acetate solution in Calcutta prior to shipment. Locally they were soaked in water and in solutions such as blackboy gum, sugar, bluestone-soda ash mixtures, copper naphthalate and sodium silicate and dipped in solutions of sodium acetate, soda ash, milk of lime, gypsum, superphosphate, plaster of Paris and "Rot Proof." In practice, however, the labour involved in dipping and drying makes the process unsuitable.

(b) *Dusting and Spraying.*

The dusts included powdered limestone, lime, soda ash, rock phosphate, dicalcium phosphate, plaster of Paris, gypsum; the sprays were solutions of soda ash. Sprays and dusts may be used with little expense and, if effective, could be adopted as routine practice.

In 1938, in response to a request for an investigation from the Wheat and Wool Growers' Union of Western Australia, the Council for Scientific and Industrial Research stated that a thorough investigation into the causes of deterioration had been undertaken at the Perth works of the Commonwealth Fertilisers and Chemicals Limited and summarised the findings as follows:—

> The damage to the bags is apparently caused by slight traces of gases of the halogen group, which are always present in superphosphate. Fluorine is believed to be the principal destructive agent. In a series of tests carried out on bags stacked in piles, it was found that the maximum damage was done in the upper layers, and the upper side of the bags invariably suffered more than the lower side. A protective treatment has been developed which has given satisfactory results in practical tests. This treatment involves immersing the bags in a solution of sodium acetate, and costs approximately 9d. per dozen bags to apply. It has been found that the damage can be minimised by arranging stacks in such a way that free evaporation of moisture and corrosive gases can occur on the upper surfaces of the stack. The damage usually occurs in the trucks when moist vapour collects under the tarpaulin and recondenses during the night.*

SCOPE OF THE PRESENT INVESTIGATIONS.

The present investigation considered (1) the nature of the superphosphates; (2) factors likely to be responsible for the damaging effect on bags and tarpaulins; (3) measures likely to assist in the protection of the bags.

(1) Nature of the Superphosphates.

The superphosphates investigated fall into two groups.

(i) Those manufactured from phosphate rock from Nauru, Ocean and Christmas Islands, which are very low in hydrochloric acid but contain hydrofluoric acid.

*Letter of September 23, 1938, Department of Agriculture file No. 837/38.

(ii) Those manufactured from Egyptian† rock phosphates containing appreciable quantities of hydrochloric but little, if any, hydrofluoric acid.

Expressed as HCl, the chloride content of the first group is from 0·01 to 0·02% and, in the second group, 0·09% for Sofaga and 0·16% for Kosseir.

The use of Christmas Island and Egyptian rock phosphates in place of those from Nauru and Ocean Island brought about a change in manufacturing processes. For the production of the required percentage of water soluble phosphate, Christmas Island rock required from 5 to 10% more acid than the Nauru and Ocean Island Rock. The Egyptian material was readily attacked by the acid. As the Egyptian phosphate was of lower grade than the Christmas Island, the commercial superphosphates were made by mixing the two types in appropriate proportions to obtain a mixture containing 22% total phosphoric oxide, with 20·25% being water soluble. The new superphosphate gave a free acidity (as H_2SO_4), generally of from 1·4 to 1·6% as compared with 0·8 per cent. to 1·0 per cent. for Nauru and Ocean Island superphosphates.

Certain manufacturers arranged to neutralise part of this excess acidity by the incorporation of small amounts of finely ground limestone and it was found that the practice was sufficiently satisfactory for it to be adopted as a routine measure. The spraying with soda ash solution of the upper sides of the topmost bags in the trucks, where contact with the railway tarpaulins would be made, was found to afford further protection.

(2) FACTORS LIKELY TO CAUSE DETERIORATION OF JUTE MATERIALS.

The deterioration of jute materials under varying conditions was investigated. Materials were studied, firstly in stacks designed to simulate actual railing conditions and, secondly, under laboratory conditions.

The materials were tested under standard conditions with apparatus kindly lent by Messrs. Cuming Smith and Mt. Lyell Farmers' Fertilisers Limited.* Measurements were made of the tensile strength of the jute material. At first, tests were made with strips of jute sacking exactly one inch in width and cut across the bag so that the strength of the shot fibres was determined. As this method proved cumbersome and slow, later tests were made with five-ply jute twine of the type commonly used for sewing bags.‡

Tests were first of all carried out with new jute materials and there was found to be a very substantial variability in the tensile strength of untreated fabric and twine. With strips of material the tensile strength varied from 125 to 197 lbs. for strips one inch in width. The majority of the tests were in the neighbourhood of 140 lbs. and this figure is adopted as the normal tensile strength of a jute strip one inch in width. With five-ply jute twine the range was from 25 to 52 lbs. and the normal tensile strength is taken as 36 lbs.

† The Egyptian rock phosphates were shipped from two Red Sea ports, Kosseir and Sofaga. Shipments were kept separate in the investigation but nothing is known regarding the source of the material represented by each shipment.

* The laboratory tests on jute materials and tensile strength determinations were made in the Department of Agriculture laboratories. The chemical determinations were made in the Government Chemical Laboratory.

‡ Collateral tests on railway tarpaulins and similar fabrics were made by Dr. C. R. Kent at the Railway Laboratory, Midland Junction.

From the tests on new material it became obvious that the humidity of the air above the superphosphate affected the tensile strength. Whereas the normal tensile strength of twine may be taken as 35 lbs., six strings under examination in bottles averaged more than 40 lbs., the difference being due to the fact that the humidity above the superphosphate was greater than that of the atmosphere. The string absorbs moisture and increases in tensile strength; drying decreases the tensile strength. Owing to this variability, conclusions can only be based on major differences.

On the other hand, experimental conditions were severe and it is thought that differences of practical importance are so magnified that the observed effects on the twine are highly significant.

In tests on damaged material, the extent of the damage affects the accuracy of measurement. Jute materials damaged by superphosphate are discoloured brownish or reddish; the fibres become brittle and, in cases of severe damage, are furry in appearance and powder in the fingers. Under these conditions they cannot be bent or tied and tests were therefore made by means of a straight-out pull. In consequence, the resultant figures may be somewhat higher than could be expected from bags being handled in transport. Where the tensile strength for twine is less than 5 lbs. the destruction may be regarded as practically complete; a tensile strength of 20 lbs. indicates severe damage.

Tests on damaged jute materials followed three main lines of investigation—(i) tests on superphosphate bags returned from the country; (ii) laboratory tests to determine the action of superphosphates from rocks of different sources on jute materials; (iii) determination of relationship between temperature and severity of damage.

(i) *Tests on Superphosphate Bags Returned from the Country.*

In order to obtain information regarding the damage to superphosphate bags during the 1942 despatch, arrangements were made in February for the collection of representative bags by district officers of the Department of Agriculture. These were obtained subsequent to the hottest part of the weather and also subsequent to the initiation of control measures by the manufacturers.

It is well established that, in railway trucks, damage is always most severe on the upper sides of bags in contact with the tarpaulins. Maximum temperatures develop at these points and there will be a tendency for volatile substances to be liberated and concentrate where temperatures are highest. Whether condensation during the cooler night periods is a factor is not known; in the later laboratory tests (p. 9) no condensation occurred and the action was very severe.

Standard strips were selected to represent varying positions of the bags in the trucks and, where information was available, the upper and lower sides of the bag. Examination of the bags showed that deterioration was not uniform—some parts were relatively strong and other parts almost rotten.

Tests of tensile strength showed that three specimens of the eleven bags containing superphosphate were seriously damaged. These were despatched

early in the season and apparently suffered hot weather in the trucks. The remaining eight bags were normally sound for superphosphate bags.*

(ii) *Laboratory Tests to Determine the Action of Superphosphates from Rocks of Different Sources on Jute Materials.*

In this section of the investigation two series of tests were made.

In the first series, standard strips of sacking were placed in stoppered bottles containing superphosphate. Some strips were in contact with the superphosphate; others were suspended in the vapour phase above it. The bottles were exposed to the weather on a roof for a number of days before the determination of the tensile strength. These tests were carried out during two periods, January 22nd to 28th and February 3rd to 13th, 1942. The first period was the hotter, the maximum solar radiation temperature being 70°C. and the average 63°C., compared with 64°C. and 60°C. for the second period.

The results of the first test are given in Table 1, and from them the following principles emerge:

(a) There appears to be no relationship between the amount of the excess acidity and the damage to the fabric.

(b) Superphosphate containing chloride† but little or no hydrofluoric acid, as shown by freedom from etching in the glass containers, caused most severe damage.

TABLE 1.

Superphosphate.	Excess Acidity. (% H_2SO_4)	Water Soluble Chloride as % HCl.	Tensile Strength. lbs.
A.—Superphosphates causing moderate to severe etching.			
Nauru I.	0·6	nil	82
Christmas	1·6	nil	79
Nauru I. plus 0·5% HF.	...	nil	52
Nauru I. plus 0·7% H_2SO_4	...	nil	48
B.—Superphosphate causing little or no etching but containing chloride.			
Kosseir I.	0·9	·16	39

In the second series of tests, five-ply jute twine was substituted for the strips. Eight-inch lengths of twine were used in 2-ounce bottles containing 20 grams of superphosphate. At least six pieces of twine were used for each test and all treatments were carried out in an electric oven at the required temperatures for a period of three days and four nights.

* Tests carried out at the same time on bags containing Potato Manure E (of which potassium chloride is a constituent) despatched in hot weather, showed very serious damage.

† Egyptian phosphate rock is mined at a depth of about 1,000ft. and occurs as a layer below ground water level. The rock contains a small amount of water soluble chloride. One sample analysed by Mr. Walker, of Cresco Fertilisers Ltd., contained 0.36% water soluble chloride, equivalent to 0.59% sodium chloride. Another, representing another shipment, contained water soluble chloride equivalent to 0.64% sodium chloride. The ground water is probably somewhat saline and the deposit of salt is left on the rock when dried prior to shipment.

Tests were made with superphosphate and also with ground rock phosphate from Nauru Island, Christmas Island, Kosseir and Sofaga. In contact with superphosphate, damage always occurred but the extent varied with the nature of the superphosphate and the temperature. Untreated rock proved to be entirely inert both when in contact and when the jute was in the vapour phase. There is no doubt that the active agent is liberated as a result of the treatment with sulphuric acid.

(iii) *Relationship Between Temperature and Severity of Damage.*

This section of the investigation dealt with the effect of temperature on the different types of superphosphates and on superphosphates manufactured from rock phosphate to which chlorides had been added.

Enquiries and preliminary investigations had indicated that temperature was an important factor in the deterioration of jute materials and that, in the vapour phase, damage only occurred above a certain temperature. Investigations on jute twine were carried out in the laboratory under conditions ranging from room temperature (21° C.) to an oven temperature of 75°C. and the results are set out in Table 2.

TABLE 2.

Temperature. °C.	Superphosphate.							
	Nauru.†		Christmas.†		Kosseir A.‡		Sofaga A.‡	
	Contact.	Vapour.	Contact.	Vapour.	Contact.	Vapour.	Contact.	Vapour.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Room Temperature	32	41	39	40	39	46	46	50
45	26	35	32	36	15	37	21	32
50	18	40	29.	38	12	43	....	....
60	7	33	15	35	1	18	7	46
70	4	14	5	33	1	9	2	20
75	3	8	2	21*	....	....	....	....
Free Acidity % H_2SO_4	0·6		1·6		0·9		1·59	
Water Soluble Chloride % HCl	nil		nil		0·16		0·11	

* Very variable duplicates. † Room temperature range 19°C. to 27°C.
‡ Room temperature range 18°C. to 22°C.

In this test the two groups of superphosphates were found to behave somewhat differently. In the fluoride group, deterioration in contact increased more or less regularly with increase in temperature, the Nauru becoming damaging at about 50°C. and the Christmas Island at about 60°C. In the vapour phase no activity was apparent until about 70°C., which temperature may be regarded as threshold for excessive damage in this group. Etching of the glassware in contact with the superphosphate suggests that hydrofluoric acid is the causative agent. In the chloride group, deterioration in contact occurred at a lower temperature both Kosseir and Sofaga becoming damaging at about 45°C. The Kossier proved more severe and in the vapour phase was damaging at 60°C. Hydrochloric acid, formed by the action of sulphuric acid on the original chloride, appears to be the causative agent.

The effect of chlorides in superphosphates on the tensile strength of jute twine was further tested on an experimental scale by adding various chlorides to Nauru rock phosphate prior to acid treatment in the manufacture of superphosphate. Sodium chloride, calcium chloride and magnesium chloride were used but, as the results were similar, only figures for sodium chloride are given. These are shown in Table 3, where they are compared with superphosphate from Kosseir rock.

TABLE 3.

Temperature.	Chloride Content (as % HCl).			
	Nauru phosphate.	Nauru phosphate plus sodium chloride.		Kosseir phosphate.
	None.	0·102.	0·94.	0·16.
	lbs.	lbs.	lbs.	lbs.
50°C. contact	31	10	1	12
vapour	42	43	16	43
60°C. contact	18	2	zero	1
vapour	40	29	6	18
70°C. contact	12	2	zero	1
vapour	39	40	9	9

The results show conclusively the extremely damaging effect of superphosphate made from rock containing chlorides. Excessive damage occurred both in contact and in the vapour phase and the degree of damage increased as the concentration of the chloride was increased. This confirmed that hydrochloric acid liberated by the action of the sulphuric acid on the chloride in the course of manufacture is the causative agent in the case of superphosphate made from Egyptian rock.

Tests on jute materials were also made with aqueous solutions of hydrochloric, hydrofluoric and nitric acids and sodium fluosilicate and with a solution of sodium fluosilicate in 5 per cent. sulphuric acid. The tensile strength of the jute twine suspended in the vapour phase above these substances for three days and four nights at 70°C. and of dry and moist twine were as follows:—

	lbs.
3 per cent hydrochloric acid	zero
3 per cent hydrofluoric acid	27*
6·5 per cent. nitric acid	7
Sodium fluosilicate aqueous solution	37
Sodium fluosilicate in 5 per cent. sulphuric acid ..	14
Dry twine	31
Twine suspended above distilled water	45

*The bottle containing the hydrofluoric acid was waxed to protect the glass. However, the wax melted and floated on the solution so that 27 lbs. may not be an accurate figure for the damaging effect of hydrofluoric acid on the jute fabric.

These tests further confirmed that hydrochloric acid was the most damaging substance although it is possible that all of these agents may take part in the damage which occurs in the vapour phase. No explanation of the effect of the sodium fluosilicate in 5 per cent. sulphuric acid is offered.

(3) MEASURES LIKELY TO ASSIST IN THE PROTECTION OF THE BAGS.

This section of the investigation concerned treatment of the bags and treatment of the superphosphate, and materials were studied firstly in stacking tests (in which bags containing different superphosphates were stacked in the open under tarpaulins to simulate railway conditions) and secondly in the laboratory.

(i) *Stacking Tests.*

Stacking tests were designed by manufacturers and carried out at two metropolitan factories. Both bags and superphosphates were subjected to treatment and, after being stacked for about a month, the bags were tested in the laboratory. The results of two separate tests are given in Tables 4 and 5 respectively.

TABLE 4.

Super Mixture.	Super Treatment.	Bag Treatment.	Tensile Strength of Sacking 1 inch wide.	
			Upper side.	Lower side.
			lbs.	lbs.
Xmas-Egypt	2% $CaCO_3$	None	94	118
,,	None ...	Lime dust	86	122
,,	,, ...	Soda-ash solution, ½ hour ...	72	100
,,	,, ...	Soda-ash dust	70	125
,,	,, ...	Soda-ash spray, 30 gm/bag ...	56	90
,,	,, ...	Limestone dust	25	72
,,	5% phos. rock	None	24	76
,,	None ...	Dicalcium phosphate dust ...	23	86
,,	,, ...	Phosphate rock dust	18	76
,,	,, ...	None	18	75
,,	,, ...	Rot proof solution, ½ hour ...	18	82
,,	,, ...	Gypsum solution, 48 hours ...	14	105
,,	,, ...	None	12	62
,,	,, ...	Lime solution, 48 hours* ...	12	46
,,	,, ...	Immersed in water, 48 hours ...	10	96
,,	,, ...	Gypsum dust	10	40
,,	,, ...	Super solution, ½ hour	8	64

* Bag appeared completely rotted in patches.

In Table 4 the treatments are arranged in order of increasing deterioration of the fabric on the upper sides of the bags as they lay in the stack. From the results given, it is obvious that mildly alkaline substances, either mixed with the superphosphate or impregnated in the bags, are protective, the best effect being obtained by mixing 2% ground limestone with the

superphosphate. Soda ash used either as a dip, dust or spray, proved almost as effective. Other treatments were of little or no use. Soaking in superphosphate solution hastened deterioration and immersion of the bags for half an hour in lime solution proved highly damaging.

TABLE 5.

Sample	Superphosphate or Super. Mixture.	Free Acidity (% H_2SO_4).	Super. treatment—Per cent. of ground limestone* added.	Bag treatment—Upper sides sprayed with soda ash solution.	Tensile Strength of Sacking 1 inch wide (lbs.).	
					Upper Side.	Lower Side.
13	Nauru Island	1·03	none	none	22	58
7	Christmas Is.	1·19	none	none	32	66
10	Egyptian	2·30	none	none	30	52
2	Christmas-Egypt mixture	1·75	none	none	8	34
15	do.	1·75	none	0% soln.	54	52
18	do.	1·75	none	20% soln.	72	44
3	do.	....	2	none	21	44
16	do.	....	2	10% soln.	78	42
19	do.	....	2	20% soln.	89	60
4	do.	....	4	none	48	84
17	do.	....	4	10% soln.	84	78
20	do.	....	4	20% soln.	120	79

* Contains about 60% $CaCO_3$.

Table 5 generally confirmed the results of Table 4 and emphasised that damage is most severe on the upper sides of the bags in contact with the tarpaulin. In this test 2% ground limestone was insufficient to afford more than very slight protection but 4% gave considerable protection. The variation in the results of the two tests is due to differences in weather conditions. The amount of limestone added must, therefore, be adjusted to meet the needs of each type of superphosphate* and must be sufficient to allow for temperature variations likely to occur during transit.

(ii) *Laboratory Tests.*

The laboratory tests followed two lines of investigation: the protection afforded by incorporation of calcium carbonate in the superphosphate and the reduction of the proportion of acid used in preparing the superphosphate.

(a) *Incorporation of Calcium Carbonate.*—Throughout these tests finely divided precipitated calcium carbonate (Merck) was used and the required quantities were thoroughly mixed with the superphosphate.

The first series of tests were run in conjunction with the assessment of damage to strips of jute sacking by superphosphate exposed on the roof in February, 1942 (p. 5), the superphosphate in this case containing from 2% to 6% of added calcium carbonate. The tensile strength of the sacking is given in Table 6.

*Experience in a factory in 1943 indicates that more than 5% ground limestone may cause setting of the superphosphate. If less than 3% is used, adequate protection of the bags may not be accomplished.

TABLE 6.

Superphosphate or Superphosphate Mixture.	Tensile Strength of sacking 1 inch wide (lbs.). Amount of precipitated calcium carbonate added.			
	None.	2%.	4%.	6%.
Nauru	110	150	...	...
Christmas	129	129	144	136
Egyptian	102	132	136	146
Kosseir	35	128	172	...
Mixture { Christmas 84% ... Egyptian 14% ... Limestone 2% ...	128	150	152	...

In this table only contact figures are given as, with the exception of Nauru superphosphate which for some unaccountable reason showed deterioration, no damage was observed in the vapour phase. The table shows the severe damage caused by Kosseir superphosphate in contact with jute and, further, confirms the results of stacking tests on the efficacy of added calcium carbonate. The weather during this period was not excessively hot.

Standard laboratory tests using jute twine were then carried out on the effect of addition of 2% precipitated calcium carbonate to Nauru and Christmas Island superphosphates over a range of temperatures from 19°C. to 75°C. The results are given in Table 7.

TABLE 7.

Temperature. °C.	Tensile strength of jute twine (lbs.) in contact with— Nauru Superphosphate.		Christmas I. Superphosphate.	
	Without $CaCO_3$.	With 2 per cent $CaCO_3$.	Without $CaCO_3$.	With 2 per cent. $CaCO_3$.
	lbs.	lbs.	lbs.	lbs.
19–27	32	38	39	40
45	26	37	32	42
50	18	36	29	33
60	7	30	15	27
70	4	36	5	22
75	3	34	2	20

These results show practically complete protection for Nauru superphosphate up to 75° C. but only 60° C. for Christmas Island.

Standard tests were next carried out on Kosseir and Sofaga superphosphates with varying added amounts of calcium carbonate at 70°C., the results being given in Table 8.

TABLE 8.

(Tests made at 70°C.)

Superphosphate.	Per Cent. of Calcium Carbonate added.	Tensile Strength of jute twine.	
		Contact.	Vapour.
		lbs.	lbs.
Nauru	none	4	14
	2	36	33
Christmas	none	5	33
	2	22	35
Kosseir	none	1	9
	2	9	34
	10	4	36
	12	11	38
Sofaga	none	2	20
	2	12	37
	10	12	38
	12	32	34

These results are discouraging in that large amounts of calcium carbonate were necessary to afford protection to jute bags when in contact with Kosseir and Sofaga superphosphates at high temperatures. Protection in the vapour phase was satisfactory with 2% added calcium carbonate.

(b) *Reduction in the Amount of Sulphuric Acid used in Manufacturing the Superphosphate.*—As it was first thought that the increased acidity of the new season's superphosphate (p. 3) was an important factor in promoting the damage observed in the 1941/42 season, the effect of using less than the customary amount of acid was investigated. Standard tests were made on jute twine, using first the usual amount of acid in the manufacture of the superphosphate and then 95, 90 and 85% of this amount. The results are given in Table 9.

In each case the superphosphate was allowed to mature for at least one month before testing.

In no instance does this table indicate any significant difference in the damaging effect resulting from variations in the amount of acid used. Furthermore, the free acidity of the superphosphate was always substantial, irrespective of the amount of sulphuric acid used in its preparation. It seems that the responsible agent is released in damaging amounts in the initial stages of the reaction between the acid and the rock; the reaction between the acid and the rock phosphate does not go to completion and there is always a residue of free sulphuric or phosphoric acid in the superphosphate which decreases slowly with time during storage. The residue of unattacked rock in the superphosphate, which is not acted on by the remaining acid, does not protect the bags from damaging agents. This conclusion is supported by the finding (in Table 4) that rock flour was ineffective as a protective agent.

TABLE 9.

Rock.	Proportion of acid used in manufacture.	Free Acidity % H_2SO_4.	Water Soluble Chloride (%HCl).	Tensile strength of jute twine in contact with superphosphates (lbs.)	
				45°C and 55°C.	70°C.
				55°C	
Nauru	100	1·17	less than 0·01	24	8
	95	1·27		30	2
	90	1·02		31	3
	85	0·70		27	4
				45°C.	
Christmas ...	100	2·04	less than 0·01	29	16
	95	1·47		35	14
	90	1·34		34	14
	85	1·07		38	11
Kosseir	100	1·24	0·16	13	1
	95	1·22		16	1
	90	1·14		17	1
	85	1·22		10	1
Sofaga	100	1·59	0·11	21	2
	95	1·44		17	3
	90	1·29		25	1
	85	1·10		14	2

Damage in the vapour phase occurred only with the Kosseir and Sofaga superphosphates at 70°C.

DISCUSSION AND CONCLUSIONS.

(1) DAMAGING AGENTS.

The tests reported above give conclusive evidence of the damage to jute materials by superphosphate under a range of conditions. The damage results in brownish-reddish discoloration of the fabric, loss of tensile strength and, in cases of severe damage, extreme brittleness.

The deterioration is due to a number of agents of an acidic character, of which hydrochloric, hydrofluoric and excess sulphuric or phosphoric acid are the most important.

Of these, hydrochloric and hydrofluoric acids are the most active—hydrochloric being the more severe—and they are responsible for the excessive damage which occurs over a short period of time. They are occluded in the granules of superphosphate and act very severely on the fabric with which they come in contact. They act also in the vapour phase as the temperature rises sufficiently to cause a substantial volatilisation, hydrochloric becoming damaging at lower temperatures than hydrofluoric. The other two acids, sulphuric and phosphoric, probably exert a mild action on the fabric in contact and will become severely damaging when this contact is prolonged over a long period.

Temperature is another factor of prime importance. In superphosphates containing hydrochloric acid fabrics in contact are subject to excessive

damage as the temperature rises above 45°C. and, in the vapour phase, above 60°C.; with hydrofluoric acid types excessive damage occurs in contact above 50°C., and, in the vapour phase, above 70°C.

The presence of chloride in Egyptian phosphate rock (p. 5, footnote) presents a problem in the manufacture of superphosphate and there is need for an investigation into the nature of the chloride. If it occurs solely as the water soluble form, it may be possible to remove it by leaching before manufacture.

(2) CONTROL MEASURES.

(i) *Facilitation of Escape of Volatile Acid Vapours.*

Factory practice may be modified to facilitate the escape of volatile acid vapours, both in the mixer and in stacks.

(ii) *Neutralisation of Acids.*

Running tests should be made to determine the amount of alkaline substances to be incorporated with the superphosphate to give maximum protection, having regard to the nature of the superphosphate and temperature conditions. Such a treatment would result in some dilution of the superphosphate and a reduction in the water soluble phosphoric oxide content. Experiments indicate, however, that the addition of ground limestone does not reduce the value of the phosphate in wheat growing.

(iii) *Spraying.*

Protection is afforded by the spraying of alkaline solutions on the upper surfaces of the topmost bags in the trucks immediately under the tarpaulins where optimum conditions for deterioration occur.

(iv) *Transport.*

Despatch of superphosphate manufactured from rock containing chloride should be reduced to a minimum during the hottest months of the year. Delays in transport should be avoided.

(v) *Bulk Storage on Farms.*

Farmers should arrange to store the superphosphate in bulk as far as possible and a cement floor will be found convenient. After emptying, the bags should be well washed with water. A small amount of lime may be added to the washing water but strong suspensions of lime should be avoided. (P. 8, Table 4.)

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2.—A REVISION OF THE WESTERN AUSTRALIAN SPECIES OF *TRIODIA* R. BR.

By Nancy T. Burbidge, B.Sc. (Hons.).

Read, 14th March, 1944.

Communicated by C. A. Gardner.

The revision of the species of this genus in Western Australia was undertaken as a result of investigations concerning the management and carrying capacity of certain natural pastures in the north-west of the State. The investigations were being made by officers of the Institute of Agriculture of the University of Western Australia. The species are all xerophytic grasses with a characteristic tussock habit and pungent pointed leaves. Although the genus is found throughout tropical and arid Australia, it is only in Western Australia that there is a definite pastoral zone dependent on these grasses. The zone, speaking very broadly, is a triangle with its base line along the Ashburton River and its apex at Broome. To the south of this area, the country grades into the mulga zone with *Acacia* spp. as the dominant forms. To the east is desert country where more *Triodia* occurs but, by reason of poor water supplies and general inaccessibility, no leases have been taken up. South of this pastoral zone some species of *Triodia* do occur but they are of no value to the pastoralist.

The name "spinifex" is commonly, but erroneously, attached to these grasses. The word is so widely and so consistently used by pastoralists that it is accepted in some places in this paper to avoid further confusion. Actually the name *Spinifex* belongs to another genus of grasses which, in this part of Australia is commonly found on sand dunes near the coast. Some of the species of *Triodia* have been called "porcupine grass" though not in this State and this name will not be used in this paper.

Economic Value in Western Australia.

By far the most important species is *Triodia pungens* since it is the only one which is readily eaten by sheep. It is also widely distributed throughout the more arid sections of the State which have a predominantly summer rainfall. It is a variable species and edibility is related to the growth form, as well as to the age of the plant. This will be further discussed under the species description. *T. pungens* is tolerant of different soil conditions and it ranges through the whole of the pastoral zone, described above, and extends right across to Queensland. As will be shown it has been collected, by the author, over a considerable area of the pastoral zone and field notes concerning variability are available. So far as edibility is concerned trials carried out at Warralong Station, Coongan River, by officers of the Institute of Agriculture, showed that the digestibility of this species is approximately 50 per cent.

With reference to the ecological association of which *T. pungens* is the dominant species it should be realised that herbage resulting from the growth of annual fodder plants is scanty in most seasons, in comparison with the flush of growth which appears in mulga country. The perennial grasses form a closed community and, except where they are burnt back, there is little ephemeral growth. The practice of burning back the tussocks when

they become old, coarse and unpalatable is used throughout the area. This means that there are odd patches in all paddocks, where a certain amount of herbage is available to the grazing animal. As a general rule this is entirely eaten out by the sheep before they will touch the rough fare offered by the tussock grasses. Top feed is not important in the spinifex areas.

The majority of the rest of the species come under the heading of Buck Spinifex, *i.e.*, very rigid-leaved forms in comparison with *T. pungens* which is commonly called "Soft Spinifex." The value of Buck spinifexes to the pastoralist is very small. In most cases the seedheads are eaten by stock.

Some species regenerate less readily than others. As a whole the spinifex association is an extremely stable one, ecologically. This is a fact of prime importance when the risks of soil erosion as a result of denudation by grazing animals is considered. So far the spinifex plains do not seem to be showing any marked deterioration but along the rivers which serve as stock routes there has been serious depletion as a result of overgrazing or of floods following heavy stocking. However in such habitats the *Triodia* association gives way to a savannah type with Eucalypts and annual grasses.

T. pungens is the only resinous species among these discussed in this paper. The gum is used by natives for many purposes, *e.g.*, for fastening axe or spear heads to their shafts. So highly is it valued by the uncivilised tribes that it is an important item in bartering and even serves as a form of currency. It is believed that the seeds of a number of species are eaten.

HISTORY AND LIMITATION OF THE GENUS.

Triodia was described by Robert Brown in Prodromus Florae Novae Hollandiae p. 182 : 1810. The name refers to the tridentate character of the lemmas. Bentham (Benth. et Hook. F. Gen. Pl. iii. 1175, 1883) and Hackel (Engl. u. Prantl., Nat. Pflanzenf. IIAbt. 2. 68) took a wide view of the genus and included certain North American species. However, Stapf in his arrangement of the material in the Kew Herbarium (Hubbard in Hook. Icones Pl. Vol. iv. t. 3336, 1937) restricted the name of the Australian species and placed most of the American material in *Tridens*. This is a much more satisfactory arrangement. The lemmas in the American material are definitely three nerved and the outer nerves are more or less marginal. In the Australian species the nerves are in three groups of three or more, each group ending in the lobes and where the group is reduced to a single nerve it is not uncommon to find vestiges of nerves at the base. There is also a tremendous difference in the general habit of the two sets of species. While the American species are small tufted grasses the Australian ones are large tussocks with rigid, pungent pointed leaves. The odd geographic range must also be considered. There is a general resemblance between the habitats the two genera occupy.

Brown described four species of which *T. pungens* is the type for the genus. None of the type material was collected in Western Australia. Bentham (Fl. Austral. vii. p. 605 : 1878) however, had the use of a larger amount of material and he listed *T. pungens* and *T. microstachya* for this State as well as his own species *T. Cunninghamii*. Concerning the first of these Hubbard (Hook. Ic. Pl. Vol. iv., t. 3336, 1937) has declared that the western material represents a distinct species. Nevertheless the author, as a result of field work, is convinced that the variations existing bridge the gap of the eastern material and definition, even as a variety, is not possible. This decision is supported by the agreement in foliar anatomy. *T. microstachya* is reported for the North-West Coast owing to a speciman collected by Cunningham. This specimen was seen, by the author, while at the Kew Herbarium in 1940 and it represents

a distinct species. It is described herein as *T. angusta*. *T. Cunninghamii* Benth. is not a satisfactory species. It was based on a specimen collected by Cunningham in the Cambridge Gulf, on the extreme northern coast of Western Australia. The specimen was seen at Kew and consisted of a few bare culms and a rather battered panicle most of whose glumes were empty. Neither the description nor the key characters are sufficient to distinguish it from *T. pungens*. Specimens collected on the 80-mile Beach by the author agree closely with the description but, with others, they grade into *T. pungens*. Bentham's name is accordingly regarded as a synonym in this paper.

Brown's species *T. procera* and *T. microstachya* were collected on the Upper Victoria River by Mueller. Gardner (Enum. Pl. Aust. Occ. 1930) accepted these as Western Australian. However the locality belongs to the Northern Territory so pending their collection in this State they cannot be included in this paper. Brown's remaining species *T. irritans* was also recorded for the State by Gardner (l.c.) who has collected it from several localities.

T. Mitchelli Benth. was recorded by Gardner (l.c.). However Queensland material, which had been compared with the type material, was made available through the courtesy of Mr. S. T. Blake, of the University of Queensland. This showed that our specimen was not *T. Mitchelli* but a variation of *T. pungens*.

Other species which have been described since the publication of the Flora Australiensis include *T. Basedowii* Pritzel (Fedde, Repert. xv. 356 : 1918). *T. lanigera* Domin (*Journ. Linn. Soc. Lond.* xli. p. 278 : 1912) and *T. longiceps* J. M. Black (*Trans. Roy. Soc. S. Aus. liv.* 59 : 1930). The most recent publication is *T. Wiseana* C. A. Gardner (*Journ. Roy. Soc. W. Aust.* xxvii. 166 : 1942).

T. intermedia Cheel (*Svensk Vet-Akad. Handb. U.S. lii.* No. 10. 4. 1919) does not belong in this genus.

Four new species are described herein.

GENERIC DESCRIPTION.

Spikelets arranged on capillary or short peduncles or more or less sessile and secund on lateral branches of the panicle. Spikelets ovate to linear, 3–20 florets of which the upper two or three are empty and sterile. *Glumes* equal or almost so, scarious or indurate ; 1–13 nerved ; obtuse, acute, acuminate or aristulate ; nerves often obscure ; glabrous or scabrid. *Lemmas* tridentate with nerves in three groups each consisting of three to seven nerves or reduced to three nerves with or without vestiges at their bases. The entire portion scarious, hardened or becoming yellow horny-indurate, glabrous or pubescent. The lobes either mere indentations of the apex, in which case the midlobe may be formed of the prolongation of the central nerve, or there may be three scarious or rigid lobes as long as or longer than the entire portion. In the former group the nerves are distinct in the entire portion of the lemma, in the latter they are very obscure in the entire part and conspicuous in the lobes owing to associated strands of chlorenchymatous tissue. *Palea* shorter than the lemma, usually about as long as the entire portion ; the nerves may be scabrid and prominent or with a thin membranous wing. *Lodicules* two, cuneate or obovate. *Stamens* three. *Anthers* oblong or lanceolate, in some species dehiscing through subapical slits.

Perennial, xerophytic tussock-forming grasses. The tussocks may be up to two metres in height and the same in diameter. The growth form may be discoid, pyramidal or annular due to the dying away of the central portion.

The leaves appear terete owing to the folding together of the two upper or adaxial surfaces. In the field the leaf blade is not closed so that it appears v-shaped in cross section. In herbarium specimens the blades are closed so that they appear u-shaped in cross section. The blade may be glabrous, glaucous, or pubescent. It is pungent pointed in all western species. The ligule is a row of short hairs across the whole of the top of the sheath. Since the blade is narrower than the sheath there is a ridge, left on either side of the base of the lamina, which may become auriculate and which usually bears hairs longer than those of the ligule. Sheaths are glabrous, resinous or pubescent. Panicles are erect with branches spreading at anthesis.

Bentham refers to the glumes as keeled but most of the western material have glumes either rounded or very slightly keeled. One mistake commonly made in connection with this genus is that the leaf is described as convolute. As will be seen by the above description this is not the case. References to open and narrow panicles are of little use since at anthesis all western species, at least, spread their branches out at right angles to the main rhachis. The spreading is due to a small swelling which appears at the base of each branch. In practically all herbarium material the branches have returned to the erect position.

The closest affinity is with *Plectrachne* Henr. This genus is distinguished from *Triodia* because of its awn like lobes to the lemmas. In view of the variation already present within *Triodia* this seems an inadequate feature on which to base a generic distinction.

Other affinities are with *Astrebla* and *Danthonia*.

KEY TO THE WESTERN AUSTRALIAN SPECIES.

Lobes of lemmas with conspicuous nerves and as long or longer than the entire portion where the nerves are obscure.

  Lobes of the lemmas scarious. Leaf sheaths not resinous, more or less woolly pubescent

    Lateral lobes of the lemmas obtuse .... *Basedowii*

    Lateral lobes of the lemmas acuminate .... *lanigera*

  Lobes of the lemmas rigid, erect or spreading. Leaf sheaths resinous .... *pungens*

Lobes of lemma short (except in *T. Wiseana*). The nerves visible, under a lens, in both the base and the lobes.

  Lower glume with three to seven nerves. Lowest lemma 5–8 mm. long.

    Lateral lobes of the lemmas acute. Nerves of the palea winged.

      Lobes of lemma nearly as long as entire portion. Sheath orifice with stiff glistening hairs 4–5 mm. long. Leaves not glaucous .... *Wiseana*

      Lobes of lemmas short. Sheath orifice with short woolly hairs. Leaves glaucous .... *brizioides*

    Lateral lobes of the lemmas obtuse. Nerves of palea not winged .... *irritans*

Lower glume one nerved. Lowest lemma 2–4 mm. long	
Spikelets pedunculate. Nerves of the palea winged.	
Lemmas thin, scarious. Glumes obtuse	*Fitzgeraldii*
Lemmas indurate. Glumes acute or acuminate	*longiceps*
Spikelets sessile. Nerves of palea not winged. Glumes acuminate or aristulate.	
Lemmas glabrous or with few hairs. Sheath orifice without auricular appendage. Leaves glaucous	*angusta*
Lemmas pubescent on back and along margin. Sheath orifice with fringed appendage. Leaves not glaucous	*secunda*

Species.

Triodia Basedowii *Pritzel* in Fedde, Repert xv. 356 (1918).

This species differs from *T. lanigera* Domin in the obtuse lateral lobes of the lemmas, the membranous palea and more obtuse glumes. It may be distinguished from *T. pungens* R. Br. by the woolly not resinous leaf sheaths.

It forms a dense tussock which, owing to the death of the older central parts, may become annular or crescentic. *Culms* erect or more or less ascending ; internodes short, branches at the upper nodes. *Leaves* rigid, sheaths woolly-tomentose, especially towards the junction with the lamina, sometimes becoming almost glabrous ; ligule a row of woolly hairs shorter than the tomentum of the auricular ridges, the latter hairs continued onto the base of the base of the " petiole " ; the lamina is conduplicate, pungent pointed, minutely striate owing to ridges of tissue developed above the nerves, glabrous, 5–25 cm. long, 1·5 mm. wide, the petiole-like base 2–4 mm. long. *Panicle* narrower and shorter than in *T. lanigera*, with fewer spikelets ; 8–12 cm. long. *Spikelets* spreading and truncate, pedunculate on the short panicle branches. *Glumes* enclosing the lemmas and almost as long as the spikelet, lanceolate or oblong, obtuse or shortly acute, membranous and becoming scarious, 9–13 nerved, the central nerve reaching the apex, equal in size, 6–10 mm. long, 3–4 mm. wide, minutely scabrid and slightly ciliolate towards the apex or quite glabrous and entire. *Lemmas* 5–8 per spikelet, the lower 3–5 fertile and hermaphrodite, lateral lobes obtuse, central lobe more or less acuminate, lateral lobes 4 mm. long, central lobe 5 mm. in the lowest floret, whole lemma softly pubescent and the margins of the lobes ciliolate. *Palea* obovate or oblong, the apex incurved over the floral organs, minutely pubescent, nerves scabrid, texture membranous. (Pl. I., fig. 1.)

So far as is known this is a useless species like *T. lanigera.* It is widespread in the southern north-west and arid interior to the South Australian border.

Distribution.—Lake Way Station, Wiluna, *Melville* (*Burbidge* No. 451) ; north-east of Wiluna, *Stewart* (*Burbidge* 446) ; 60 miles east of Meekatharra, *Gardner*, 2367 ; Sandstone, *Gardner* ; locality unknown, Hann, 1903.

Triodia lanigera *Domin* in *Journ. Linn. Soc. Lond.* xli. 278 : 1912.

Differs from *T. pungens* in the scarious (not rigid) lobes of the lemmas, the scarious, many nerved glumes, and the glaucous foliage with woolly, not resinous, sheaths.

Coarse perennial tussock-forming grass. *Culms* ascending, many noded, branching at the upper nodes, internodes short, more or less woolly, especially immediately below the nodes. *Leaves* glaucous, the sheaths much longer than the internodes, tomentose or becoming glabrescent in the older parts ; ligule a row of short hairs, the tomentum of the sheath continued on to the petiole-like base of the lamina. The lamina rigid, pungent pointed, conduplicate, glabrous on the abaxial and scabrid on the adaxial surface, striate under a lens, 10–20 cm. long, 2 mm. wide, the petiole-like base 3–5 mm. long and narrower than the lamina which is much narrower than the sheath. *Panicle* erect, loose, spreading at anthesis, branches with woolly hairs at their bases. *Spikelets* cuneate with spreading florets, shortly pedunculate. *Glumes* lanceolate or oblong, rounded on the back, scarious, 9–13 nerved, apex acute, acuminate or shortly aristulate, the margin minutely ciliolate, 8–12 mm. long, 4 mm. wide. *Lemmas* commonly 6–8 of which the lower 4–6 are hermaphrodite, the rest with anthers or empty ; sharply divided into an indurate horny base 2–3 mm. long, in which there is little or no indication of the nerves, and the three scarious lobes each of which is traversed by a group of 3–5 nerves, the central nerve of each group reaching to the apex of the lobe, the nerves bounded by a narrow strip of chlorenchymatous tissue ; lobes acuminate and minutely ciliolate, the lateral ones 4–6 mm. long and the central one 7–10 mm. in the lowest lemma ; the whole lemma softly pubescent. *Palea* obovate or oblong, curved in over the floral organs, the base commonly indurate and the apex membranous, 3 mm. long in the lowest floret, the nerves ciliate and scabrid. (Pl. I., fig 2.)

The spikelets are reminiscent of those of *Danthonia bipartita*.

This species is completely worthless to the pastoralist except for the possibility that the seedheads are occasionally sought by hungry stock. The rigid, pungent pointed, dry leaves are quite unpalatable. It is found in the arid summer rainfall areas of the State.

Distribution.—Between Ashburton and Yule Rivers. *Clement* (type seen at Kew Herbarium) ; Warralong Station, *Anderson* (*Burbidge* No. 447 and 453), also *Melville* (*Burbidge* 454) and *Burbidge* 1222 (the last near Shaw River) ; Abydos Station south-west of Marble Bar, *Stewart* ; South of Ashburton River, *Gardner* 6233 ; between Gascoyne and Fortescue Rivers, *H. S. King* ; Mia Mia Station, Minilya River, *Gardner* 3203 ; Minilya River, *Gardner* 3209, 4109, 6219 ; Lyndon near Carnarvon. *Meadley* M77.

Triodia pungens *R.Br.* in Prodr. Fl. Novae Holl. p. 182 : 1810 ; C. E. Hubbard in Hook. Icones Pl. Vol. iv. pt. ii. t. 3336 ; *T. viscida* Roem et Schult. Sys. Veg. ii. 599 : 1817 ; *Festuca viscida* F. Muell. Veg. Chath. Isl. 59 : 1864 ; *Triodia Cunninghamii* Benth. in Fl. Austral. vii. 606 : 1878.

Perennial tussock grass. The growth form is very variable and is further discussed below. *Culms* glabrous, erect or ascendent or forming long stolons with tufts of short erect culms at the apex. *Leaves* conduplicate, the blade more or less open when growing ; sheaths coated with a resinous secretion. Former descriptions refer to the leaves being resinous. In all specimens examined, both in the herbarium and in the field, it was found that the resin is only present on other portions of the plant where they are in contact with

the sheaths. At the orifice of the sheath there are long hairs on the auricular ridge and these are usually matted together with the resin. The ligule is a row of short hairs extending right across the inner face of the top of the sheath. The lamina is narrower than the sheath. The petiole-like base is shorter than in most species. The margin of the lamina is scabrid and the apex pungent but the point is not rigid as in "Buck Spinifex." *Panicle* pyramidal at anthesis but in most herbarium material the branches erect and the spikelets clustered together, variable in size and from 10–40 cm. long. *Spikelets* linear to ovate (in spikelets with fewer lemmas), with more or less imbricate lemmas, shortly pedunculate or almost sessile along the panicle branches, 4–11 florets. *Glumes* lanceolate, ovate or oblong, concave, becoming indurate ; nerves 5–7 usually obscure ; glabrous or minutely scabrid ; the apex acute, shortly aristulate or ragged. *Lemmas* divided into an entire, indurate basal portion which covers the floral organs and three rigid, erect or spreading acuminate lobes which vary from as long as to longer than the basal part ; the latter apparently without nerves, pubescent at the base and up the middle of the abaxial surface ; the lobes with 3–5 nerves each bounded by a green strip of chlorenchymatous tissue, and a thin scarious margin which is minutely ciliolate. *Palea* elliptical, slightly longer than the entire portion of the lemma and usually curved over the floral organs, apex ciliate, nerves narrowly winged. *Anthers* oblanceolate, dehiscing from sub-apical slits. *Caryopsis* oblong. (Pl. I., fig 3.)

Despite the wide variation in the growth form and in the dimensions of the parts of the spikelets, the author, after due consideration of both herbarium material and field information has come to the conclusion that varieties in the taxonomic sense cannot be distinguished. It has been found that spikelet variations cannot be correlated with differences in habit. Thus growth forms with quite different values as feed cannot be recognised simply from a herbarium specimen. The differences between the majority of the material are differences of degree only, *e.g.*, relative length of spikelets, relative length of glumes to lemmas, etc. Again, Hubbard's view (Icones Pl. iv. ii. t. 3336 : 1937) that the western material represents a distinct species, has been disagreed with for the same reason. The western specimens have a more heavily indurate base to the lemma, which is usually yellow and horny but intermediates occur. The spikelets in our material have more florets but this has been found to depend partly on the vigour of the plant, which is related to the habitat or to the time of year in which the panicle develops, which again is a matter of habitat. Apart from field notes more than a hundred separate collectings were available on which to base the conclusions expressed herein.

Nevertheless the growth forms that are evident in the field are described below so that some idea of the variation of the species is made available. All these forms and less distinct ones, not described, have their significance for the pastoralist. The grazing animals (sheep) show definite preferences for some forms. This is a result not only of different food values but also because of more direct reasons for palatability, *e.g.*, the leaves are less resinous, or less pungent, or less scabrid and fibrous. The habitat effects the form to a certain extent though broadly speaking there are few major soil alterations throughout the area over which this species is distributed (except 80 Mile Beach country).

The forms are divided into two groups :—(*a*) forms with a dense cushion-like tussock which does not develop long runners, (*b*) forms with a tussock formed chiefly by loosely tangled stolons or runners which develop semi-independent tussocks at their ends. The former group is the larger.

Group (a) includes the following :—

(i) A large domed tussock up to a metre or more in height and about the same in diameter. The general habit is dense. The sheaths are very resinous and on older culms the resin is dried to a white incrustation. The leaves are dark green, the blades about 20–25 cm. long and scabrid along the margins which are spread apart. The panicle is large and 50–70 cm. higher than the tussock. The panicle branches are long, the lower ones bearing 6–10 spikelets, each of the latter bearing more than six florets.

This is a coarse form which is eaten in the young stages. Later the sheep turn to it only in case of necessity. It is common on the plains along the De Grey River and southwards to Marble Bar.

(ii) Dark green tussock smaller than the preceding to which it approaches closely. The leaves are usually very scabrid but there are plants with smooth margined leaves. It differs in lacking the white incrustation on the older portions, in its smaller size and its smaller panicle whose branches bear 4–5 spikelets. It is a very resinous form.

It is, perhaps, the most common form of soft spinifex. It was found by the author on all inland stations visited. It is, in some places, subject to variation due to habitat. For example, at Mount Edgar Station, south-east from Marble Bar, it grew as a small compact tussock on the higher rocky ground and as a more vigorous larger tussock in the hollows. It is eaten in the young stages and also later except where there is a high proportion of dead leaves.

(iii) Low flat tussock about 30 cm. high and up to 2–3 metres in diameter. The central or older portion commonly dies off. In this case the dried culms disintegrate and blow away. The panicle is short, 10–20 cm. long and compact, *i.e.*, the branches arise close together.

This form was well developed in the country adjacent to the Coongan River, a tributary of the De Grey. It appeared to be fairly palatable to sheep.

(iv) Small dense tussock 30–40 cm. high with very yellowish green leaves. This was an easily recognisable form in the field. The leaf blades are softer than in other forms and the blades are closed so that the leaf appears terete. The panicle is again short and only about 20–30 cm. higher than the tussock. The spikelets are very squat and ovate.

Common along the De Grey plains. It occurs in small areas amongst (i) and (ii) from which it can be easily separated.

(v) Hill Spinifex. The tussocks on the rocky slopes are very short culmed. The leaf blades are variable and in the gullies may grow to more than 30 cm., though usually they are 15–20 cm. long. The panicle has fewer spikelets, which are narrower and with the lemmas more imbricate. The glumes are rather scarious, not indurate, and the lobes of the lemmas are shorter than in the plains forms. The plants are less resinous.

Found on all hilly country in the Pilbara area. It is apparently an ecotype, being restricted to its habitat. The hills on which it grows are stony, arid, and barren.

(vi) Coastal Spinifex. The plants are characterised by their long leaves, 30–50 cm. long, thin and wiry as in (iv). The general habit is a dense central butt with a loose mass of surrounding culms. The panicle has spikelets which are consistently smaller than those of the inland forms. The smaller

ones agree so closely with those described for *T. Cunninghamii* Benth., that this name is regarded as a synonym of *T. pungens*. There are, however. intermediate sizes so that it is not possible to make a variety.

This form is only found on the grey sand and loam soils of the coastal plain along the 80 Mile Beach.

Group (b) has two forms :—

(vii) Runner Spinifex. Practically the whole of the plant is made up of long stolons. In one place a tussock was seen which was more than three metres in diameter but the possible range varies down to a metre. The panicle has no very special characteristics except that the glumes are usually longer than the three lowest lemmas instead of as long as the lowest lemma but this may not be constant. The leaf blades are scabrid and open when growing.

This form was found in rather small patches all through the plains country along the De Grey River. It grows on country adjacent to the rivers but not actually along the banks. It appears to set very little seed and does not regenerate easily like the first four forms.

(viii) Pindan Spinifex. The growth form is very like that of (vii) but there is a cushion tussock with radiating stolons. It is fairly resinous and there are no special panicle features.

This type is mentioned as it occurs in a different ecological community. Spinifex pindan is an *Acacia*—tussock grass association. Either *Triodia* or *Pleetrachne* is found in the lower stratum. Spinifex pindan occurs in the " desert " country inland from the coastal plain of the 80 Mile Beach and to the north of the De Grey River. Form (viii) appears to be less palatable to sheep than is (vii).

Distribution.—Anna Plains, *Burbidge* ; Nalgi, *Burbidge* ; Wallal Downs, *Burbidge* ; Pardoo, *Burbidge* ; De Grey Station, *Burbidge* also *Anderson* : Poondanah Siding, *Burbidge* ; Port Hedland, *Fitzgerald* 64, 1558 ; Shaw River, *Anderson* (*Burbidge* No. 465) ; Mulyee Station, *Anderson* (*Burbidge* 463) ; Coongan Station, *Anderson* also *Melville* also *Burbidge* ; Warralong Station, *Anderson*, also *Melville* also *Burbidge* ; Gorge Range, *Burbidge* ; Soda Creek, on Coongan Station, *Burbidge* ; Muccan Station, De Grey River, *Burbidge* ; Kitty's Gap, *Burbidge* ; Eginbah Station, *Burbidge* ; Marble Bar, *Burbidge* ; Mount Edgar Station, *Burbidge* ; Stony Hills to south of Mount Edgar, *Burbidge* ; Meentheena Station, *Blair* ; Dampier Archipelago, *Walcot* ; Nichol Bay, *Sewell* ; Roebourne, *Polak* ; Warambie Station, Roebourne, *H. G. Meares* ; Ashburton River, *Morrison* ; Cane River, *Gardner* 3074, 6238 ; Beadon, *Gardner* 3069, Port Sampson, *Gardner* 1638.

Triodia Wiseana *C. A. Gardn.* in *Journ. Roy. Soc. W. Aust.* xxvii 166: 1942.

This species can be identified by the peculiar hairs developed on the auricular ridge, at the top of the leaf sheath, and along the margin of the lower portion of the lamina. The lemmas have three acute lobes and the nerves are visible in the basal portion as well as in the lobes. The paleas have a well developed wing on each nerve.

Culms ascending in dense tussocks ; internodes short, glabrous and smooth ; branching from the upper nodes. *Leaves* rigid, divaricate, with glistening hairs 4–6 mm. long developed on the auricular ridge at the top of the sheath and along the lower part of the lamina. The hairs arise in

groups from small swellings. The ligule is a row of short hairs. Tho lamina is conduplicate, minutely striate, pungent pointed, 10–20 cm. long, 2 mm. wide. *Panicle*. 6–12 cm. long, loose, and open with spikelets on scabrid capillary branches. *Spikelets* 8–10 mm. long. *Glumes* lanceolate or oblong, apex acute or almost aristulate, commonly trinerved but sometimes having axillary lateral nerves, subequal, glabrous, indurate, 4–5 mm. long. *Lemmas* imbricate, 3–9, indurate, lanceolate with three rigid acute or acuminate lobes from half to nearly as long as the entire portion ; three groups of three nerves continued almost to the base ; with a row of hairs up the centre of the abaxial surface and others along the margins ; lowest lemma 4–6 mm. long. *Palea* oblong 3–4 mm. long, membranous or scarious, nerves winged. The margins of the wings usually protrude slightly in the spikelet.

Gardner's specimen was, unfortunately, rather immature. The peculiar hairs on the leaves, however, showed it to be a distinct form.

Distribution.—Mount Margaret Pass, Hamersley Range, *Gardner* 3129 (type) ; near Mount Rica, *Gardner* 6422.

Triodia Wiseanna var. **brevifolia** *N. T. Burbidge* var. nov.

Laminae brevae, 5–9 cm. longae, 1–1·5 mm. latae. *Lemmata* indurata, lobi acuminati, rigidi, divaricati, 3-nervis.

Differs from Gardner's typical form in its shorter, narrower leaves with the marginal and auricular hairs less prolifically developed. These hairs are not conspicuous in the field. Apparently when growing they lie parallel to the margin. It is only in dried material that they stand out. The lemmas are more deeply lobed so that the appearance approaches that of *T. pungens*. However, the nerves are clearly visible in the base of the lemma. (Pl. II., fig. 4.)

The variety, like the typical form, is found on stony ground which, in the Pilbara area, means the arid slopes of the hills.

Distribution.—Anna Plains Station, 80 Mile Beach, *Burbidge* 1438 ; Muccan Station. De Grey River, *Burbidge* 994 ; between Kitty's Gap and Eginbah Station, *Burbidge* 995 ; Dingo Point, Eginbah Station, *Burbidge* 1044 ; between Eginbah and Marble Bar, *Burbidge* 1062 ; Mount Edgar Station, south-east from Marble Bar, *Burbidge* 1126 ; Nullagine Road south from Mount Edgar, *Burbidge* 1150, 1152 (type), 1172, 1176 ; Red Hill north of Ashburton River, *Gardner* 6371.

Triodia brizioides *N. T. Burbidge* sp. nov. : affinis *T. irritanti*, a qua lemmatibus acute lobatis, glumis aristulatis, laminis glaucis differt.

Gramen perenne, dense caespitosum. *Culmi* ascendentes, nodis superioribus ramosi, multis nodis, glabri, laeves. *Foliorum vaginae* induratae, laeves, glabrae vel sparse tomentosae, pallidae vel stramineae, ligulae ad seriem ciliorum redactae ; orificia tomentosa ; laminae angustiores vaginarum, breviter petiolatae, rigidae, glaucae, divaricatae conduplicatae, 5–12 cm. longae, 1·5 mm. latae explanatae ; apices pungentes. *Paniculae* diffusae, 5–10 cm. longae ; rhachis scabra, spiculae pedunculatae, bases pedunculorum villosae, pedunculi 6–15 mm. longi, scabri. *Spiculae* lateraliter compressae, lineares vel oblongae, pallidae, 10–20 mm. longae, 6–8 mm. latae. *Anthoecia* 7–10. *Glumae* oblongae, concavae, aristulatae, aequales, glabrae, scariosae, 6 mm. longae, 3 mm. latae, 3-nervis, apices ciliolatae. *Lemmata* lanceolata vel ovata, 9-nervis, basi pubescentis, margine barbata ; infima 5–7 mm. longa ;

trilobata ; lobi acuti, ciliolati, subaequales vel medii longiores, nervosi. *Paleae* lineares 5–6 mm. longae, basi pubescentes, bicarinatae ; alatae. (Pl. II., fig. 5.)

This grass forms a very dense hemispherical, greyish tussock 40-50 cm. in diameter. It prefers rocky slopes and is found on arid hills in the Pilbara district. It is easily distinguished from *T. irritans* by the glaucous leaves, the loose panicle in which the comparatively few spikelets are apt to hang down resembling those of *Briza maxima*, the acute lobes of the lemmas and the winged nerves of the paleas. These wings commonly protrude beyond the margin of the lemma in the spikelets.

The species is of no pastoral importance.

Distribution.—Gorge Range (between Shaw and Coongan Rivers), *Burbidge* 792 (type !) ; Kitty's Gap (between Coongan River and Bamboo Creek), *Burbidge* 979 and 984.

Triodia irritans *R.Br.* in Prodr. Fl. Novae Holl. 182 : 1810 ; *Festuca irritans* F. Muell. Veg. Chath. Isl. 59. Fragm. viii. 129 : 1874.

A perennial grass forming dense tussocks. *Culms* ascending, quite glabrous, internodes short, branching from the upper nodes. *Leaves* glabrous ; ligule a row of short hairs, the auricular ridges of the sheaths very short and bearing hairs longer than those of the ligule ; blades conduplicate, 8-16 cm. long, very pungent pointed. *Panicle* 10-20 cm. long with spikelets on capillary peduncles along the branches ; the spikelets 10-18 mm. long, 3-8 mm. wide. *Glumes* 6-9 mm. long, subequal, scarious or becoming indurate, 1-5 nerved (usually the lower glume three-nerved and the upper five-nerved), the mid nerve prominent, lanceolate, acuminate or acute, minutely scabridulous. *Lemmas* 5-10, the lower 3-4 fertile, lanceolate with a ragged obtuse apex composed of three very short lobes of which the lateral ones are membranous and the medial one a prolongation of the mid-nerve. The medial lobe may be longer or shorter than the lateral lobes. There are nine nerves in groups of three, each being associated with a lobe, the nerves visible almost to the base of the lemma, which is clothed on the lower abaxial and marginal surface with silky hirs. The lowest lemma 5-8 mm. long. *Palea* linear or slightly oblanceolate, obtuse, shorter than the lemma or almost as long, glabrous or pubescent in the lower half, the nerves scabrid. (Pl. 2, fig. 6.)

A "Buck Spinifex" which is associated with the arid portions of the southern interior. The Kalgoorlie specimen has a narrower panicle and smaller spikelets than the other specimens but seems hardly distinct enough to separate as a variety. Further collections may serve to elucidate the point.

Distribution.—Meekatharra, *C. A. Gardner ;* Coorow, *Gardner ;* 20 miles east of Mount Holland, *Gardner ;* Kalgoorlie, *Gardner ;* near Fraser Range, *Gardner* 2851a.

Triodia Fitzgeraldii *N. T. Burbidge* sp. nov. ; *Triodia Fitzgeraldii* C. A. Gardner ms. ; affinis *T. longicepti* J. M. Black sed spiculis minoribus, lemmatibus scariosis, lobis acutis, vaginarum marginibus hirsutis differens.

Gramen perenne, caespitosum. *Culmi* erecti, rigidissimi, nodis superioribus ramosi, glabri, laeves, multis nodis ; internodia brevia. *Folia* rigida ; vaginae imbricatae, pubescentes vel glabrescentes, marginibus et orifice hirsutis ; ligulae ad seriem ciliorum redactae ; laminae angustiores vaginarum, rigidae, conduplicatae, glabrae, minute striatae, breviter petiolatae, 9-20 cm.

longae, apicibus pungentes. *Paniculae* contractae, angustae. *Spiculae* breviter pedunculatae, lateraliter compressae, lineares, 4-6 mm. longae, 3 mm. latae, pallidae. *Anthoecia* 4-6. *Glumae* oblongae, obtusae, laeves, subaequales, marginibus minute ciliolatis, 1-nervo, 2·5-3 mm. longae. *Lemmata* lanceolata, scariosa, 3-nervis, 3 mm. longa, basi villosa, apicibus trilobata; lobi acuti, nervosi, minute ciliolati, subaequales. *Paleae* oblongae vel lanceoatae, 2 mm. longae, nervis anguste alatis. (Pl. 3, fig. 7.)

This species lies between *T. longiceps* J. M. Black and *T. microstachya* R.Br. It differs from the former in its smaller spikelets, scarious lemmas with acute lobes and the ciliate, pubescent leaf sheaths and from the latter in its one-nerved glumes, basally pubescent lemmas and narrowly winged nerves of the paleas. Its distinctive character was pointed out to the author by Mr. C. A. Gardner who suggested naming it after its discoverer. It is known from the type specimen only.

Distribution.—Dillon's Springs, East Kimberley, *W. V. Fitzgerald* 1643 (type !).

Triodia longiceps *J. M. Black* in *Trans. Roy. Soc., S. Aust.*, liv. 59 : 1930.

A perennial grass forming large rather loose tussocks (up to four or five metres in diameter and 2-4 metres in height) and having long stolons extending beyond. Culms smooth and glabrous, branching from the upper nodes. *Leaves* very rigid, glaucous, the sheaths and blades glabrous or minutely puberulous and with very short cilia on the orifice of the sheath; ligule a row of short cilia; apex very pungent pointed. *Panicle* 20-50 cm. long, with the spikelets shortly pedunculate on the lateral branches which spread at anthesis. *Spikelets* linear, with 6-21 florets, 8-20 cm. long, 2·5-3 mm. wide, with the lemmas imbricate or spreading. *Glumes* lanceolate or almost ovate, glabrous, subequal 3·5-4 mm. long, with one slightly prominent nerve extending to the acute or acuminate apex. *Lemmas* lanceolate or ovate, 4 mm. long, indurate, glabrous or with a basal tuft of short hairs, the nerves reduced (from three groups of three each) so that only one nerve extends to each lobe but at the base of the lemmas the vestiges of the lateral nerves of each group are more or less developed; the apex with three very short, subequal, acute lobes in the Western Australian material though, in his description, Black says the lateral lobes are obtuse with a short mucro between. *Palea* 3 mm. long, oblong or lanceolate with prominently winged nerves, glabrous, the upper half usually free from the lemma and conspicuous. (Pl. 3, fig. 8.)

In the field the general habit approaches that of *T. angusta* but it is a coarser plant and the panicle is quite distinctive. Both species show a preference for the banks of water courses and flats liable to flooding. The chief affinity seems to be with *T. microstachya* from which it differs in the one nerved glumes and the winged, glabrous palea.

Distribution.—Pardoo Station, *Burbidge* 1519; De Grey Station, *Anderson*, also *Burbidge* 1544; Warralong Station, *Melville* 28 and *Burbidge* 791; Muccan Station, *Burbidge* 911 and 965; Marble Bar, *Stewart*; Mount Edgar Station, south-east from Marble Bar, *Burbidge* 1066, 1067, 1129, 1192, 1138; Nullagine, *Melville*.

Triodia angusta *N. T. Burbidge* sp. nov., affinis *T. microstachyae* R.Br. sed glumis inferioribus 1-nervis, acuminatis, spicis angustioribus, linearibus, lemmatibus sparsim pubescentibus differens.

Gramen perenne, caespites late extensos densissimos formans et stolones elongatos emittens. *Culmi* divaricati, rigidissimi, glabri, laeves, simplices vel

basi ramosi, 6-12 nodis. *Foliorum vaginae* induratae, laeves, glaucae ; ligulae ad seriem ciliorum redactae ; laminae angustiores vaginarum, breviter petiolatae, rigidae, conduplicatae, apicibus pungentibus, marginibus ciliolatis, 12-20 cm. longae. 2 mm. latae explanatae. *Paniculae* contractae, anguste lineares, 15-20 cm. longae, 7 mm. latae ; rhachis scabra, angula ris ; spicae simplices, breviter pedunculatae, anguste lineares. *Spiculae* sessiles, secundae, lateraliter compressae, oblongae vel lineares, angustae, biserratae, pallidae, 2 mm. latae, 4-5 mm. longae. *Anthoecia* 3-4. *Glumae* lineares vel lanceolatae, acuminatae vel aristulatae, scariosae, scabridulosae vel glabrae, nervis scabridis ; inferior 1-nervo, 2-3 mm. longa ; superior 3-nervis, 3-4 mm. longa. *Lemmata* lanceolata vel anguste ovata, membranacea, 3-nervis, 2·5-3 mm. longa ; margines glabrae vol raro pubescentes ; apices trilobatae ; lobi nervati, erecti, acuti, lobi laterales paullum breviores quam medii. *Paleae* ellipticae, membranaceae, 3 mm. longae, nervis ciliolatis. *Lodiculae* 1 mm. longae. *Antherae* 2-2·5 mm. longae. *Caryopsis* O. (Pl. 3, fig. 9, a-f, fig. 11, a-b.)

In the field this species is readily distinguished from *T. secunda* by the glaucous foliage. It has a denser tussock being formed of a central tuft with radiating stolons. The stolons have terminal tufts of erect culms. The leaves have a very small auricular ridge which bears hairs about as long as those of the ligule proper. However, some material collected, by the author, at Shaw River had woolly sheaths while a specimen from Talga Gap, near Coongan railway siding, had very long hairs on the ridge. Since there is no special panicle difference which can be correlated with these leaf variations they are all included under the species. Apart from these exceptions the leaves and sheaths are glabrous in all specimens though the margins of the blades are commonly scabrid with minute teeth. The one nerved glumes serve to divide the species from *T. microstachya* R.Br., also the smaller narrower spikelets.

Cunningham's specimen from the "North-West Coast." which is listed under *T. microstachya* by Bentham in the Flora Australiensis, belongs to this species. It was identified by the author while at the Kew Herbarium in 1940.

The species is commonly referred to as Blue Buck. It is of no pastoral importance. It is a very common species and in the field, when panicles are missing, it may be confused with *T. longiceps.* It is usually found along the banks of rivers and creeks.

Distribution.—Coongan Station, *Anderson* (*Burbidge* 452 type ! and 445) ; Warralong Station, *Burbidge* 828 ; Shaw River, *Burbidge* 1216 ; Talga Gap near Coongan Siding, *Burbidge* 1051 ; Hills south of Mount Edgar, *Burbidge* 1151 ; Warambie Station, Roebourne, *H. G. Meares* ; Sandstone rocks, Gregory's Gorge, Fortescue River, *Gardner* 6296 ; Karatha, west of Roebourne *Gardner* 626.

Triodia secunda *N. T. Burbidge* sp. nov., affinis *T. angustae* N. T. Burbidge sed spicis latis linearibus, lemmatibus divaricatis, lemmatum marginibus differens.

Gramen perenne caespitosum et stolones elongatos emittens. *Culmi* erecti vel prostrati, rigidissimi, nodis superioribus ramosi, glabri, laeves. *Foliorum vaginae* induratae, tenuiter, striatae vel laeves, glabrae, pallidae vel stramineae; ligulae ad seriem ciliorum redactae ; auriculae erectae, fimbriatae ; fimbrae ciliolatae ; laminae angustiores vaginarum, breviter petiolatae, rigidae, virides, divaricatae, conduplicatae, 6-12 cm. longae, 2-3 mm. latae explanatae ; apices pungentes, margines ciliolatae. *Paniculae* contractae, anguste lineares ; spicae simplices, distantes, latae lineares, rhachi adpressae, 1-3 cm. longae. *Spiculae*

sessiles, secundae, biserratae, divaricatae, pallidae, lateraliter compressae, oblongae, 5 mm. longae, 4-5 mm. latae. *Anthoecia* 3-6. *Glumae* lineares vel lanceolatae, scabridulae, uni-nervatae, nervis scabris; inferior acuta vel aristulata, 3 mm. longa; superior trilobata, 4-5 mm. longa, lobus medius aristulatus, lobi laterales membranacei, acuti, breves. *Lemmata* lanceolata vel anguste ovata, membrancea, divaricata, tri-nervata, 3-4 mm. longa, basi pubescentia, marginibus barbata, apices trilobatae, lobi aequales, nervati. *Paleae* lineares, 3-3·5 mm. longae, basi pubescentes, nervi scabridi. *Lodiculae* 1 mm. longae. *Antherae* 2·5-3 mm. longae. *Caryopsis* O. (Pl. 3, fig. 10, a-f, fig. 11, c-d.)

The erect culms branch at the upper nodes, producing long prostrate stolons or short erect culms, so that when growing the plants often appear to be resting on stilts. The central mass of culms is surrounded by the radiating stolons which develop terminal groups of erect culms like those of the central portion. In this manner a single plant may cover several square meters in a diffuse growth about 30 cm. deep.

The leaves are a drab green when fresh. They are very pungent pointed. The sheaths turn a pale straw colour on the older stems. The auricular growths are quite characteristic of this species. Nothing like them is known. They are also remarkable because three marginal nerves on either side of the sheath extend into the auricles. The secund panicle branches with their broad spikelets and fringed lemmas serve to distinguish this species.

The common name is "Running Buck" or "Bunch Buck." The species is of no pastoral value though there are reports that it has carried sheep through dry summers when there was nothing else available. It is usually found on flats or near drainage channels too diffuse to call creeks.

Distribution.—Coongan Station, *Anderson* (*Burbidge* 460 type!); Warralong Station, *G. F. Melville* also *F. Melville.*

It was observed by the author in other localities:—De Grey Station, Pardoo Station, along the Marble Bar-Port Hedland Railway between Carlindi and Poondanah Sidings and on low flats behind Port Hedland township. None of the plants carried panicles and no material was collected. The presence of the fringed appendage on the leaf sheath is, however, sufficiently characteristic to make the identification reliable.

ACKNOWLEDGMENTS.

The author wishes to express her thanks to Professor G. A. Currie and Mr. Andrew Stewart for the use of laboratory facilities at the Institute of Agriculture, University of Western Australia; to Mr. C. A. Gardner, Government Botanist for helpful criticism and the use of the material in the State Herbarium, to which all the specimens from the Institute have been donated. Also it is only fitting to acknowledge the assistance given, in the field, by the late Mr. J. L. Stewart and Mr. Gordon Stewart of De Grey Station, Mr. Frank Hardie of Warralong, Mr. Coppin of Eginbah, Mr. Holthouse of Muccan, Mr. Taylor of Mount Edgar, Mr. Lacey of Wallal Downs, Mr. Spry of Nalgi, and many others.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. *Triodia Basedowii*, (a) spikelet, (b) lower glume, (c) upper glume, (d) lemma, (e) palea from side, (f) palea from front. (all x5.)

Fig. 2. *T. lanigera* (x5). Lettering as above.

Fig. 3. *T. pungens* (x5). Lettering as above.

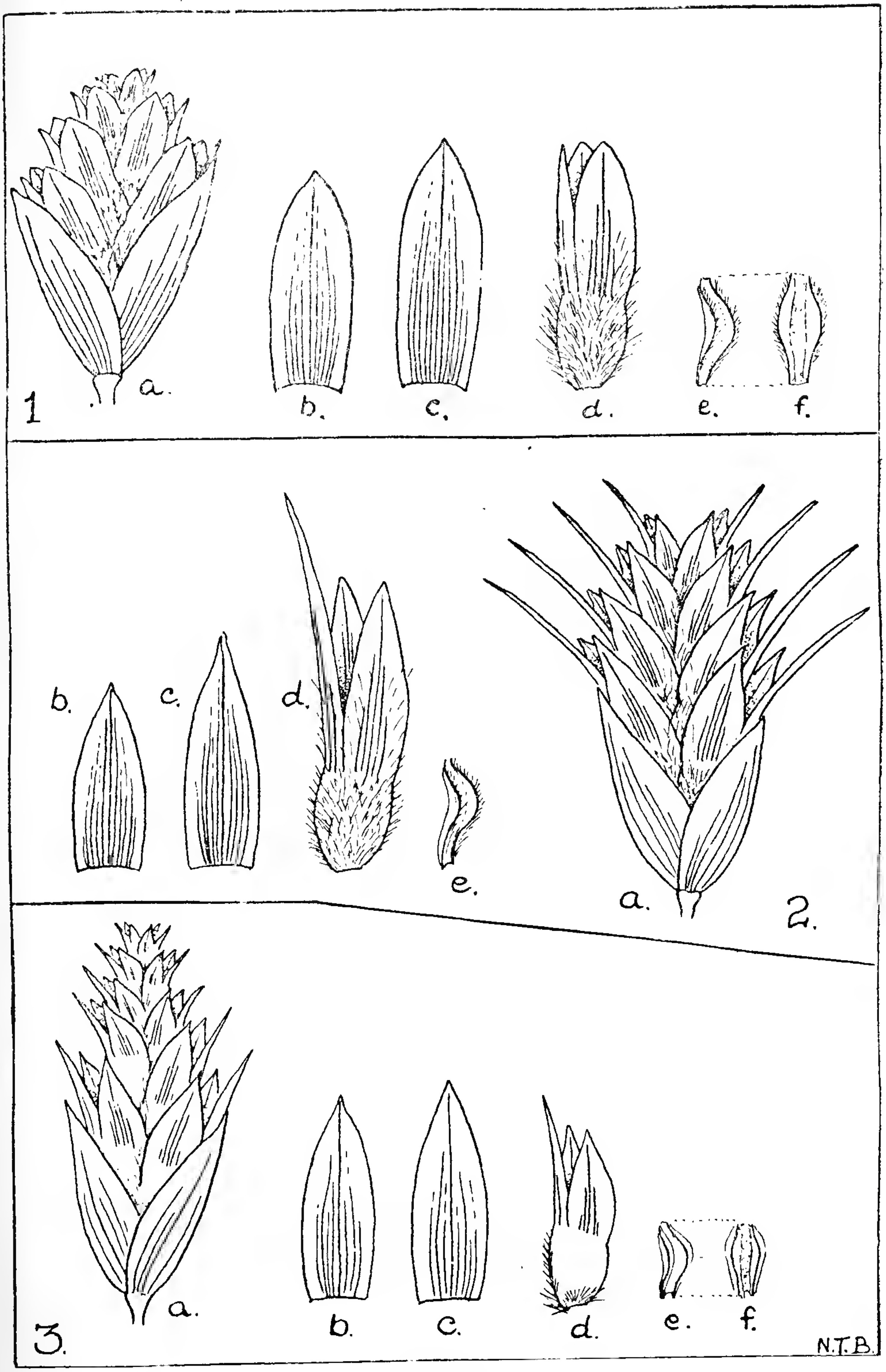


PLATE I.

PLATE II.

Fig. 4. *T. Wiseana* var. *brevifolia* (x5). Lettering as in Plate I.
Fig. 5. *T. brizioides* (x5). Lettering as in Plate I.
Fig. 6. *T. irritans* (x5). Lettering as in Plate I.

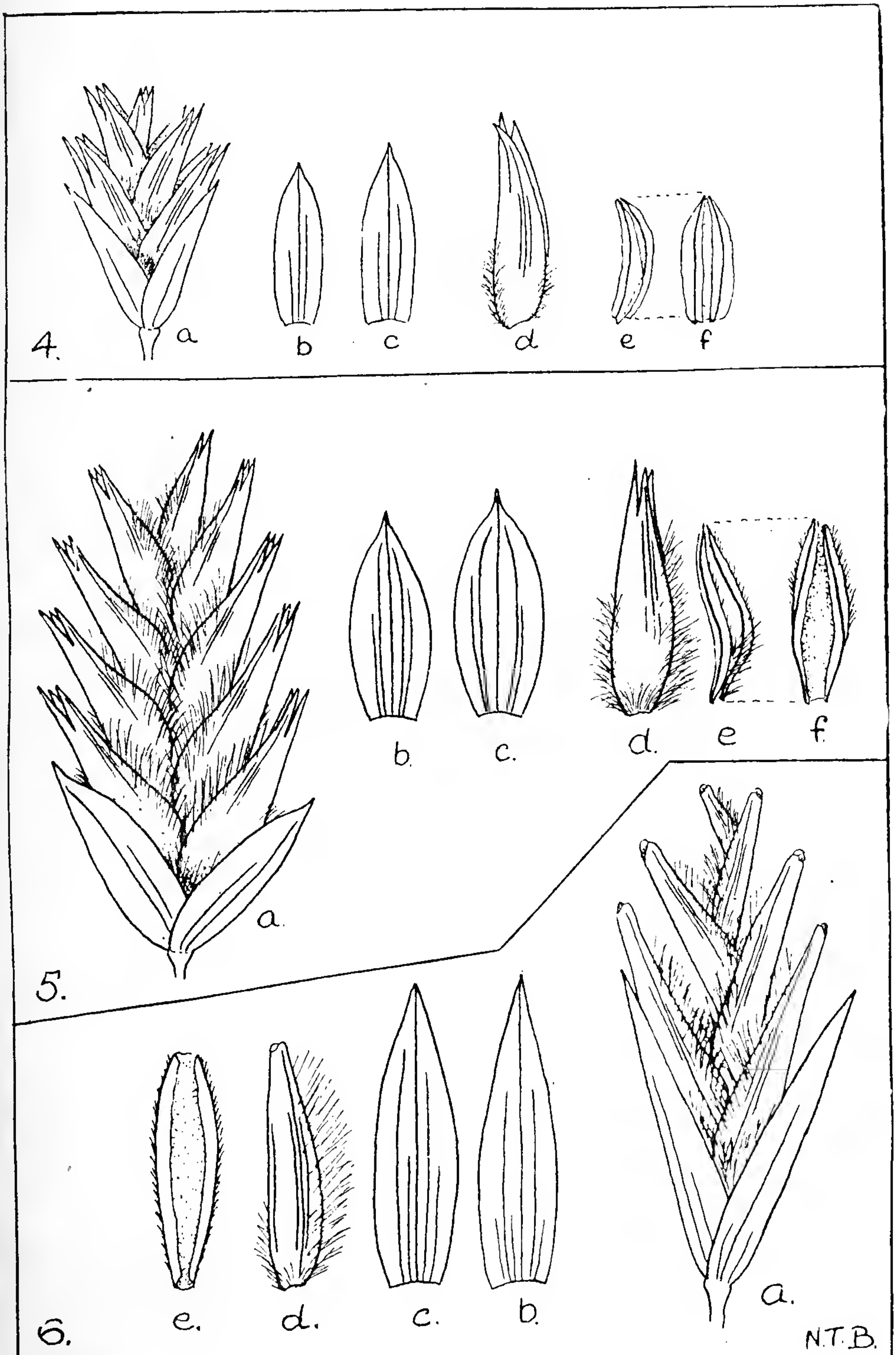


PLATE II.

PLATE III.

Fig. 7. *T. Fitzgeraldii* (x5). Lettering as in Plate I.

Fig. 8. *T. longiceps* (x5). Lettering as in Plate I.

Fig. 9. *T. angusta* (x5). Lettering as in Plate 1.

Fig. 10. *T. secunda* (x5). Lettering as in Plate I.

Fig. 11. *T. angus'a,* (a) orifice of leaf sheath from side (b) same from within showing ligule. *T. secunda,* (c) orifice with fringed appendage, (d) same from within to show ligule. (x5.)

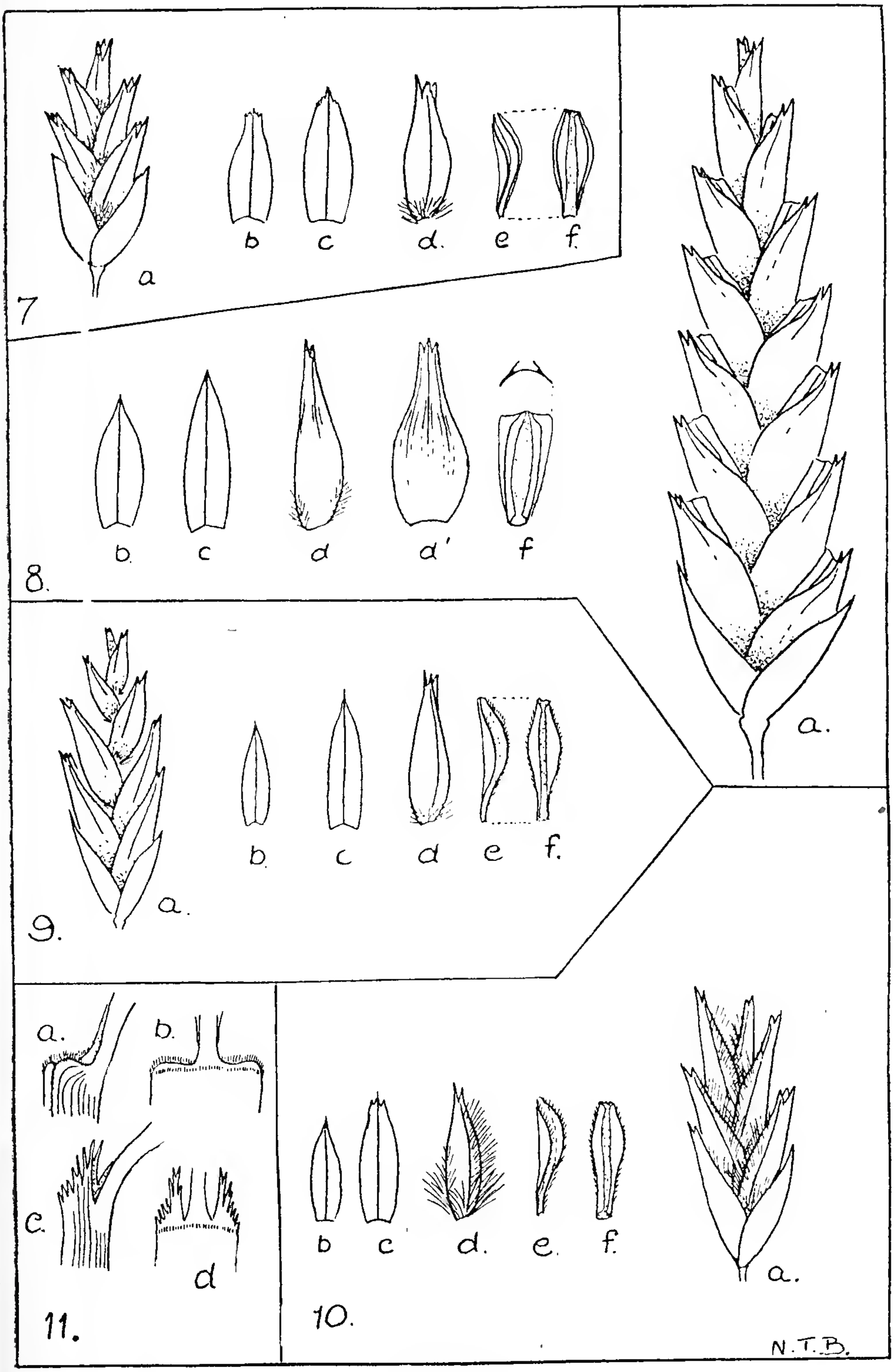


PLATE III.

3.—NEW CRUSTACEA FROM THE SWAN RIVER ESTUARY.

By J. M. THOMSON, B.Sc.
Hackett Research Scholar, University of Western Australia.

Read 14th March, 1944.

INTRODUCTION.

The species with which this paper deals were collected during the period March to December, 1943, during an investigation of the fauna occurring amongst the algae of the estuary. The collections were taken almost entirely from the western side of Freshwater Bay, where the rocky nature of the bottom provides ample hold for the algae.

As a faunistic environment the Swan estuary presents some peculiar features. The estuary is a drowned river valley but owing to the negligible tidal influence on the coast outside its mouth, there is no tidal influence in the river. Nevertheless there is a marked variation in the salinity during the year. The salinity is practically that of the open ocean in summer; whereas in winter, at least in the shallow water near the banks where the investigation was carried out, the water became practically fresh after heavy downfalls of rain. Thus in summer the fauna tends to be made up of marine and estuarine forms, in winter of estuarine and freshwater forms.

This serves to explain the variation in ecologic type of Crustacea presented here, ranging from the marine *Mesochra*, through the estuarine *Corophium* to the practically freshwater *Gladioferens*.

The species here described include two Copepods, an Amphipod, and two Isopods.

DESCRIPTION OF NEW SPECIES.

Class: COPEPODA.

Order: CALANOIDA.

Family: **CENTROPAGIDAE.**

GLADIOFERENS, Henry (1919).

Gladiferens imparipes sp. nov.

OCCURRENCE.

Amongst algae, July to December. Large numbers.

FEMALE.

Ovigerous, 1·35-1·4 mm, non-ovigerous up to 1·5 mm. Body rather robust, cephalothorax oval, its greatest width a little behind the middle. Head narrowly rounded in front and projecting below in a rostral prominence. Last thoracic segment fairly short, expanded laterally into slight lobes each bearing a slender seta.

Urosome half as long as cephalothorax. Genital segment has rounded projections at about the middle of its length and widens again posteriorly. The projections bear a group of spinules, the posterior one of which is somewhat stouter than the rest. There is also a short spine on the posterior swelling. Ventrally on the genital segment, lateral to the genital aperture and immediately behind it, is a pair of short spines. At about the same distance apart and in front of the aperture occur another pair. On each side a row of minute spinules run inward and forward from the posterior pair. Second segment of urosome half as long as first; the third is longer and rectangular; the fourth is as long as the second. Caudal rami long and slender. They are divergent and ciliated along the whole length of the inner side, and in a cluster behind the lateral seta on the outer. The lateral seta is inserted two-thirds of the distance along the margin. The other four of equal length are inserted close together on the truncated end.

Appendages: Antennule has twenty-five segments, some of the proximal being very short. Second antenna biramous, rami subequal; exopod six-segmented with three terminal setae on the distal segment. Mandibles strong and expanded, with eight somewhat rounded denticles, the outermost the largest and separated from the rest by a sinus; a slender seta stands at the inner end. Maxillae and maxillules normal; maxillipeds long and slender, the distal segments with dense setae; four borne on the second segment.

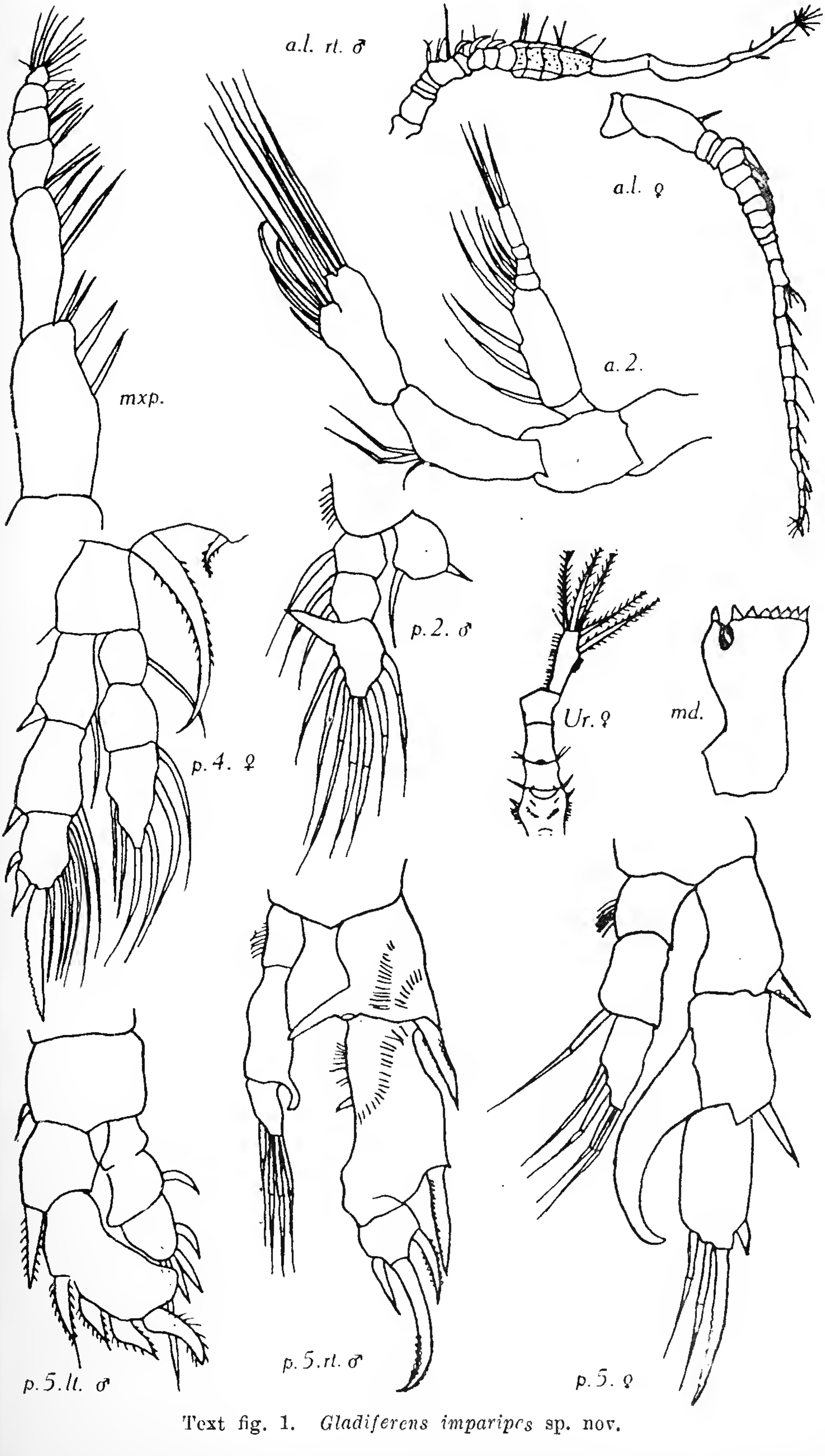
The natatory appendages are slender, with 3-segmented rami, the endopods somewhat shorter than the exopods. The second segment of the first exopod is without an external spine. The external spines are weakly denticulate. Distally each exopod bears a stouter denticulate spine and a seta. The fourth pair of appendages are asymmetrical in that the left bears a long curved coxal spine extending to the end of the middle segment of the endopod. The right coxa has a short curved sparsely ciliate spine. Coxae of all other natatory limbs have a slender straight seta. The fifth pair have the second and third segments of the exopods equal in length: a long curved spine arises from the inner side of the middle segment and reaches to the end of the third segment.

Ovisac rounded, and ventral in position.

Male.

Length 1·26 mm. Metasome narrow compared with that of female. Urosome slender, five-segmented. Caudal rami of the same relative length as in the female but without external cilia below the outer seta, and with a fifth terminal seta, more slender and much shorter than the others, between and dorsal to the two innermost setae.

Appendages: Left antennule as in female; the right modified, divided into three sections, the first of nine segments, some of which are very short, the last three with sensory setae; the second section contains five swollen segments and a long slender sixth, followed by the third section, which consists of two long curved segments which show signs of at least four incipient segments which are not divided off. The other head apppendages, including the maxillipeds are similar to those of the female.



Text fig. 1. *Gladiferens imparipes* sp. nov.

The natatory legs, except for the second and fifth, are armed as in the female and the seta on the fourth right coxa is normal, not expanded as a spine. Second pair of legs are asymmetrical, being similar to the female except that the left endopod has the proximal inner seta of the terminal segment modified into a stout spur. Fifth legs are distinctly asymmetrical; the right exopod is three-segmented, the first segment bearing a stout, inwardly directed, pointed projection; the middle and proximal segments each bear a denticulated outer spine. The middle segment is prolonged beyond its spine, and its inner surface is concave with a small spine about mid-way along the margin and a cluster of spinules proximally, but no marked basal process. The smaller distal segment bears three spines, the middle being the largest and terminally denticulate and curved. The other two are smaller, the outer somewhat the larger and denticulate, the inner smooth and more slender. The right endopod is three-segmented. At outer distal corner of its middle segment is a short spine which curves inwards. Distal segment bears four ciliate setae. The left fifth leg is shorter than the right; both exopod and endopod are peculiar in that they appear three-segmented if viewed from in front, but only two segments can be made out from behind. In the exopod it is the terminal segment which is incompletely divided. Tho basal segment bears a ciliate spine distally. The terminal segment has four, one of which is proximal to the incomplete dividing line. The terminal spine is the largest and is peculiarly bent. The inner distal corner is extended laterally into a rounded bulge with a postero-lateral groove or sinus. In the endopod it is the basal segment which is incompletely divided. There is a curved inner spine on the middle segment and three short spines, and an elongate outer spine that could almost be termed a seta on the distal segment.

Discussion.

Five species have been definitely assigned to this genus, and Nicholls (1944) suggests that *Centropages pectinatus* Brady described in 1899 from a damaged specimen is really referable to this genus, possibly referable to *brevicornis*, Henry, or *subsalaria*, Percival. In his paper Nicholls deals briefly with the probability that *subsalaria* is synonymous with *brevicornis*. The figures given by Percival are certainly very similar to those for *brevicornis*, particularly as shown by Dakin and Colefax (1940). The females of this genus are very similar and significant specific features are hard to find in the somewhat incomplete descriptions of the species. However, Kiefer for *gracilis* shows the coxal segment of the right fourth leg of the female with a straight short "feathered" seta. For *subsalaria* Percival records "a short feathered seta as in *G. gracilis*." Dakin and Colefax figure it for *brevicornis* as a straight seta. Nicholls for *inermis* shows it curved distally and rather thickly ciliated. In *imparipes* it is distinctly curved and but sparsely ciliated.

In *spinosus* the fifth endopod in the female is shorter than the exopod and does not reach beyond the centre of the middle exopod segment; whereas in *gracilis* it reaches just to the end; in *brevicornis* it is figured as reaching half-way along the terminal exopod segment, and in *subsalaria* it is stated to reach one-sixth of the distance along. However, this may not be significant, only careful examination of material could tell.

The third urosome segment of *imparipes* is relatively short compared with that of *inermis*, resembling *gracilis* in this respect. It differs from *gracilis* and agrees with *inermis*, however, in being without most of the armature on the urosome and last thoracic segment figured for *gracilis*.

Males: The structure of the fifth legs of the male differs from all other species by the hooked projection or spine coming from the middle segment of the right endopod. The two subsidiary spines on the terminal segment of the right exopod are stronger than in other species. As figured for *inermis* and *spinosus* this segment bears only one subsidiary spine in the case of the former (externally), and none in the latter. However, as Dakin and Colefax point out for *brevicornis*, Henry's drawings and descriptions are sometimes incomplete, so they may be in the case of *spinosus*. The distal inner bulge of the terminal segment of the left exopod is not shown elsewhere except for a trace in *subsalaria*.

The spur on the end segment on the left second endopod points towards the base in *imparipes* and *inermis*, but the adjacent setae have not become spinose in *imparipes* as in *inermis*, though they are shorter and less densely ciliated than in *gracilis*.

KEY TO THE MALES.

(Adapted from Nicholls).

1.	Both rami of left fifth leg 3-segmented	*spinosus* Henry
	Both rami of left fifth leg 2-segmented	2
	Exopod 2-segmented, endopod 1-segmented	4
2.	Middle segment right fifth endopod with spine	*imparipes* sp nov.
	Middle segment fifth endopod without spine	3
3.	End segment of left second endopod armed with spur at right angles to axis and 7 setae	*gracilis* Kiefer
	End segment of left second endopod armed with spur directed to base, 2 spines, 5 setae	*inermis* Nicholls
4.	Right fifth endopod 3-segmented	*subsalaria* Percival.
	Right fifth endopod 2-segmented	*brevicornis* Henry.

Distribution of the Genus: Henry described *brevicornis* and *spinosus* from fresh water in New South Wales. Dakin and Colefax record *brevicornis* as common in the New South Wales coastal lakes and record a single specimen from Port Jackson; *gracilis* and *subsalaria* occur in fresh to brackish water in New Zealand; *inermis* at the head of Spencer Gulf. The present species *imparipes* was taken in the Swan Estuary, W.A.

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Order: HARPACTICOIDA.

Family: **CANTHOCAMPTIDAE.**

MESOCHRA Boeck 1864.

Mesochra parva sp. nov.

Occurrence.

A few specimens were collected throughout the year, but they were extremely abundant in October and November, among shallow-water algae.

Female.

Length 0.45 mm. Body with genital segment divided. Abdominal somites without spines on the dorsal surface, but each has a lateral row of spines which is continued on to the ventral surface for a short distance. On the anal segment these are particularly small and they are not markedly separated from the spines lining the margin of the anal incision. The anal operculum is spineless. Caudal rami broader than long; outer terminal seta less than half the length of the inner seta, which is less than half as long as the body.

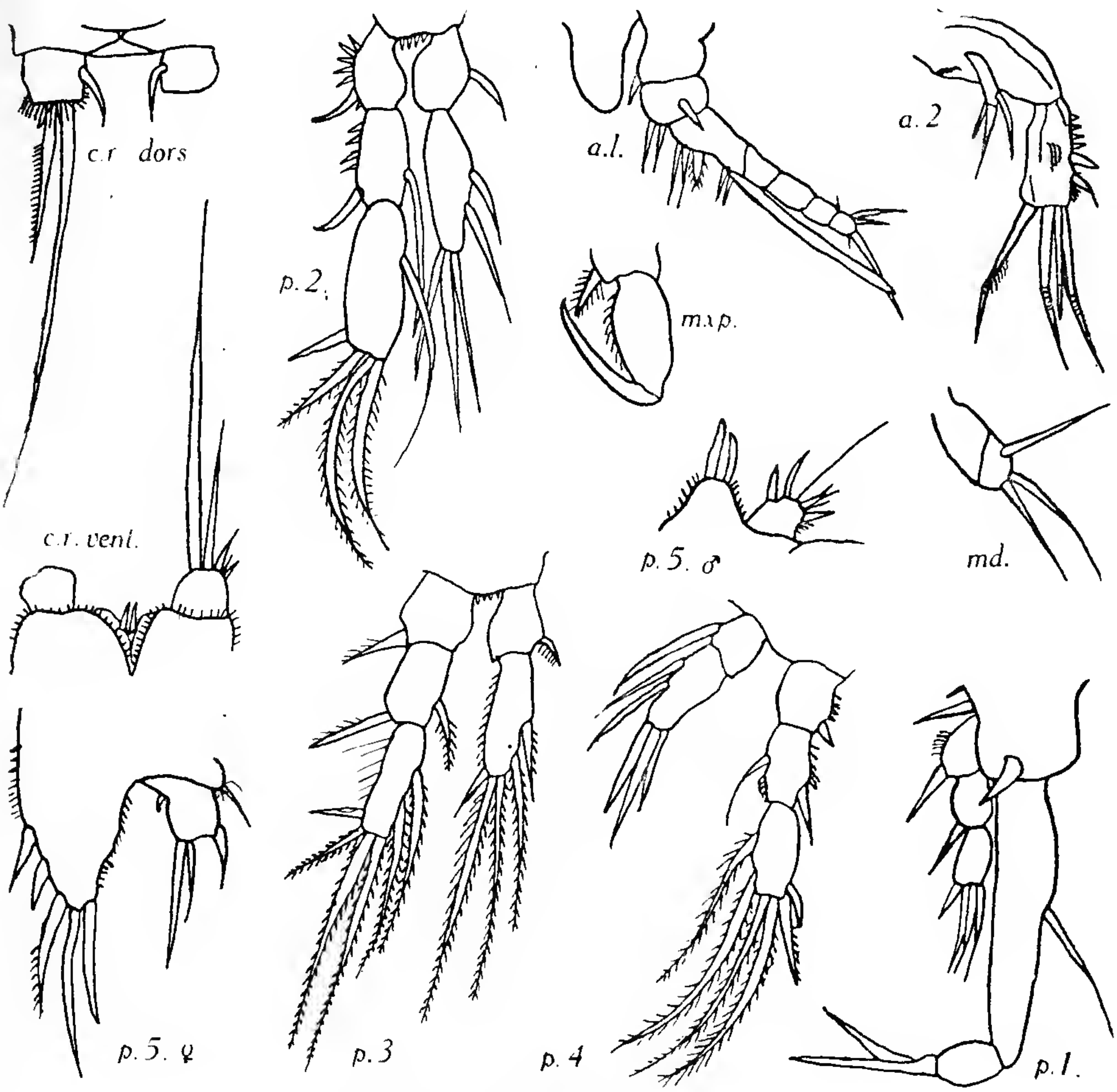
Appendages: First antenna. 7-segmented; third segment the largest, bearing a tufted spine. The aesthetase is on the third segment and extends for a short distance beyond the end of the appendage. Second antenna has basal segment elongate and narrow, undivided; exopod 1-segmented with two apical and one lateral setae, of which the outermost is the shortest and stoutest; endopod large and expanded somewhat distally, with four terminal setae, one smaller than the others, and on the outer margin a row of four to six spinules. Mandible with palp two jointed and with three distal setae. The remaining mouth parts are characteristic of the genus. Maxillipeds, subcheliform, with a seta on the basal segment near the distal end.

Natatory limbs. Legs 1-4 with 3-segmented exopods and 2-segmented endopods. The first legs have the basal segment of the endopod considerably longer than the exopod. It bears an inner marginal seta slightly proximal to the middle of the segment. The distal segment of the endopod bears two stout setae. The basal segment of the exopod has an inner seta. The arrangements of spines and setae are shown in the figures.

Setae formula.

	Endopod		Exopod		
p2	1	221	0	1	122
p3	1	221	0	1	222
p4	1	221	0	1	222

Fifth leg with basal segment extending beyond the distal and bearing five setae. The distal segment is distinctive, almost quadrangular with two stout setae at the distal corners, the inner twice as long as the outer. Next to the inner spine is a very slender seta. Between the setae are minute spinules.



Text fig. 2. *Mesochra parva* sp. nov.

MALE.

Length 0·39 mm. The expansion of the basal segment of the fifth leg has only two setae and does not extend much beyond the distal segment. The distal segment is much more normal than in the female, having four stout spine-like setae and one slender seta around the margin.

Appendages: First antenna has the proximal segments somewhat swollen and the distal segments relatively shortened. The aesthetasc is more massive than in the female and extends beyond the end of the appendage for some distance.

Colour.—White with a yellowish-green tinge.

DISCUSSION.

Some fifteen species of *Mesochra* are known. The female of *M. parva* is clearly distinguished by the unusual shape and structure of the fifth leg. The lack of a spine on the anal operculum and the seta formula serve to distinguish it from at least some of the species. Many of the species are known from the female only, so it is impossible to note specific characters for the male.

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Class: MALACOSTRACA.

Subclass: PERACARIDA.

Order: AMPHIPODA.

Suborder: GAMMARIDEA.

Family: **COROPHIIDAE.**

COROPHIUM, Latreille 1806.

Corophium minor sp. nov.

OCCURRENCE.

March to early July; tubicolous on algae.

FEMALE.

Ovigerous, length 2·55 mm. Body small, the urosome segments coalesced, rostrum small and pointed. Eye-lobes rounded and elongate. Eyes black and well developed.

Appendages: First antenna, about one third of the body length; first segment longer than second and third together (in figure appears slightly shorter, owing to bending of appendage). Lower edge of segment one with four straight spines of which the proximal is the smallest, and a little off the ventral line. There is a slight lateral bulge proximally on the first segment which bears three spines. A few long tufts of setae also occur on the segment. Segment 2 bears several tufts of setae and is cylindrical in section. Flagellum is seven segmented. Second antenna somewhat larger than antenna 1. There is a pair of spines ventrally on segment 3. Segment 4 has five well developed spines on the lower edge, a proximal pair a quarter of the distance from the proximal end, a median pair at half the distance and the fifth about an eighth of the distance from the distal end. A number of long setae also occur on this segment. Segment 5 has one median ventral spine and many long setae. Flagellum is 3-segmented. (The figure shows an abnormal appendage with a paired distal spine on the 4th segment.) Mandible with basal segment not extending beyond the base of the end segment; palp small, of two segments, each with a strong ciliated seta. Maxillae, typical. Maxillipeds sub-lamellar with basal lobes narrowly produced. The masticatory lobes are long, the inner edge fringed with slender spines; palp elongate, the last segment short but broad.

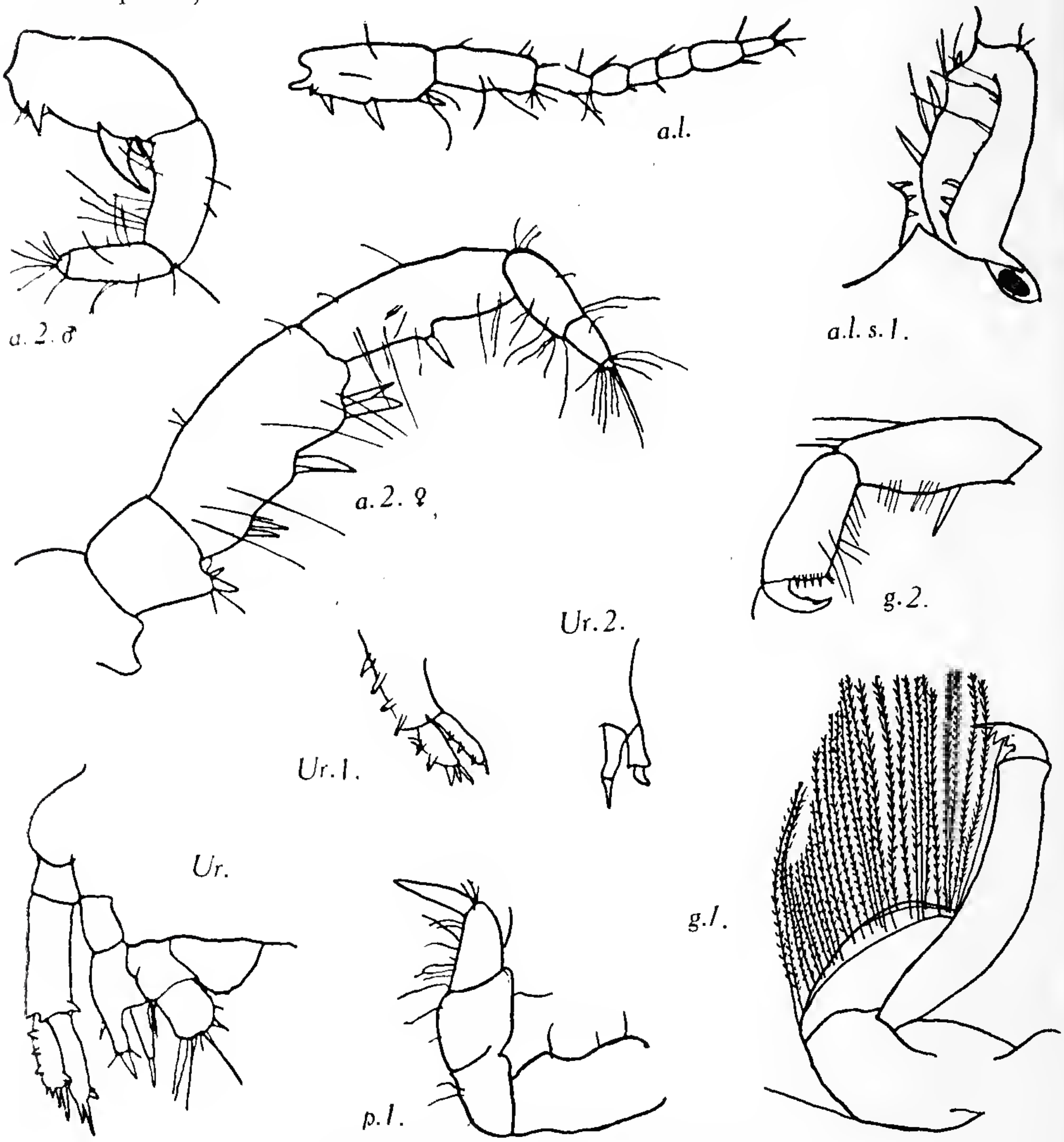
Gnathopod 1 with palm almost square with a row of four short stout spines, supplemented by short setae on the edge of the propod; dactyl with a slight accessory tooth. Gnathopod 2 larger than Gnathopod 1; not differentiated from other members of the genus. The fourth segment is closely attached to the hind margin of the fifth, and fringed with two rows of plumose setae. Propod sublinear, without a palm; dactyl with 4 accessory teeth. Pereiopods normal, the anterior two with basal segment large and broad and the merus greatly expanded, the carpus short and the dactyl considerably larger than the propod. Pereiopods 3 and 4 are comparatively stout and have two rows of spines on the outer side of the carpus. Pereiopod 5 is slender and elongate, the basal joint lamellarly expanded and fringed on both edges with long ciliate setae which however are not so dense as in other members of the group.

Branchial lamellae well-developed; none on gnathopod 2. Incubatory lamellae elongate and oval, edged with strong setae.

Pleopods with basal portion greatly expanded; rami narrow and densely setose.

Urosome, segments fused, sides hollowed out to receive insertions of uropods 1 and 2. Rami short, with stout spines on the margin externally on the first, but those of the second spineless except apically. Uropod 3 with peduncle short, ramus single and lamellar with a few long apical setae.

Telson, trapezoidal, with a terminal emargination. Number of eggs in brood pouch, 6.



Text fig. 3. *Corophium minor* sp. nov.

Male.

Length, 2·1 mm. Similar to the female except in the following points: —Antenna 1:The first segment has three spines on the lower keel and appears to be shorter than the second and third together. Length of the appendage about 45% that of the body. Antenna 2: Segment 4 twice as long as broad, with a large subterminal tooth, and a smaller tooth above it. The ventral spines found in the female are absent. Segment 5 has six tufts of setae. Gnathopod 1: Palm with a row of three spines and one large seta.

Ecology.

Builds tubes of muddy sand on algae and the rocky substratum in shallow water. They survive some degree of lowering of salinity but disappear with the onset of heavy rainfall.

DISCUSSION.

The genus *Corophium* was named by Latreille in 1806, with *C. longicorne* as the type species. Stebbing in Das Tierreich (1906) gives excellent descriptions and bibliography of the species known to him. Since his account the number of species described has been doubled and the best modern account of the group is that of Crawford (1937). He divides the genus into three sections on the character of the urosome and the insertion of the uropods. He includes useful keys to the species of each group. The present species falls into his section B, characterised by small size, fusion of the urosome segments and the lateral insertion of uropods 1 and 2, in notches on the urosome. Crawford assigned eight species to this section.

The female of *C. minor* is very like that of *C. insidiosum* (Crawford). It is however much smaller, 2·5 as compared with 4·5 mm. The relative lengths of the three basal segments of antenna 1 differ. Also both right and left dactyls of gnathopod 2 have four accessory teeth in *minor* whereas this is the case with the right only in *insidiosum*, the left having three.

The male of *minor* differs from that of *insidiosum* in the structure of antenna 1, and lesser features such as relative abundance of setae on various segments. Nor has the male of *minor* the very long rostrum of *insidiosum*. Like the female it is also much smaller than the other species.

The armature of the antennae is sufficient to distinguish *C. minor* from all other species.

Apart from the changes in armature associated with growth, normally occurring in this genus, two variations were noted. Some twenty-four females were examined. In two of these the proximal spine on the first segment of antenna 1, instead of being small, was quite large, and the second proximal was the smallest spine. In another specimen which did not differ from normal otherwise the distal spine on segment 4 of the second antenna was paired (as shown in figure) replacing in its position the more usual seta. Such variations in a small percentage of individuals was noted by Crawford. It is impossible to say without experimental breeding whether this is due to abnormal growth, or to a mutation.

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Order: ISOPODA.

Suborder: FLABELLIFERA.

Family: **ANTHURIDAE.**

CRURANTHURA gen. nov.

Cruranthura simplicia sp. nov.

OCCURRENCE.

June to September; twelve specimens being taken during this period. Among algae.

FEMALE.

Length 5·25 to 6 mm. (ovigerous). Body elongate, narrow, back broadly arched, surface smooth. Ratio of lengths of thoracic segments 9:11:10:12:12:9:4. The seventh thoracic segment is wider than the abdominal segments. Abdominal segments 2-5 fused dorsally, though the suture may still be distinguished laterally.

Head: Eyes large, situated in the prominent antero-lateral lobes. Anterior margin excavate for reception of antennae, with a conspicuous median rostral point. Dorsally there are scattered patches of dark pigment. The mouth parts are adapted for sucking.

Appendages: First antenna 4 segmented, basal segment long, widening distally. The fourth segment (flagellum) shows a distinct constriction at about two-thirds of its length, possibly indicative of a fused segment. It bears a thick bunch of setae on a slight prominence apically. Second antenna of five joints, the last densely setiferous, the basal segment the longest, penultimate the next longest.

Mouth Parts: Unfortunately only the maxilliped and second maxillae dissected out well, but as far as could be ascertained the mandible had no palp, or else a very reduced one. Second maxillae straight with short lateral teeth distally. Maxillipeds, two-segmented, the proximal portion fused to the head. The free segment is narrow distally, but much broader proximally, the two portions distinguished by a marked constriction of the inner margin.

Pereiopod 1, subchelate, propod with proximal tooth defining the palm which is only slightly oblique. There are two rows of setae on the inner side of the propod parallel to the palm. and one row on the outer side. The

carpus is cup-shaped and under-rides the propod. The ischium and basis are slightly expanded, and the dactyl is smoothly curved. Pereiopod 2, subchelate, palm linear, propod smaller than in pereiopod 1, and armed with a row of six spines. "Tooth" of the dactyl marked off by a sudden narrowing on the palmer side. From the shelf so produced a number of setae spring. Carpus and merus are very much as in pereiopod 1. Pereiopod 3, similar to 2. Pereiopod 4, with dactyl bent at an angle to the propod, but scarcely subcheliform; propod armed with two spines, one distal, the other at mid-length. The terminal portion of the carpus bears two spines. The carpus is relatively larger than in the three anterior limbs. Merus with only a slight distal expansion and the carpus does not under-ride the propod. Pereiopods 5 and 6 similar to pereiopod 4, except that the carpus is armed with three spines. Pereiopod 7 absent.

Pleopod 1 operculiform, covering the other pleopods. The outer ramus is enlarged, distal and fringed with long setae except on the inner margin; the inner ramus narrow, fringed distally on both sides. Both rami loaded with dark pigment. In Pleopod, 2-5 inner ramus not quite as long as the outer, which is wider. Endopod simple without setae, distal portion bulbous. Exopod broad with fringing setae.

Uropod basis with a few terminal setae; the lower edge produced downwards in a keel. Exopod three times as long as broad, inner edge fringed with a few long setae, with still fewer inserted on the outer edge. Endopod less than twice as long as broad, inner margin almost straight, outer margin with long fine setae.

Telson: Broadly ovate-lanceolate, setiferous at the rounded apex, otherwise bare. Convexly arched dorsally.

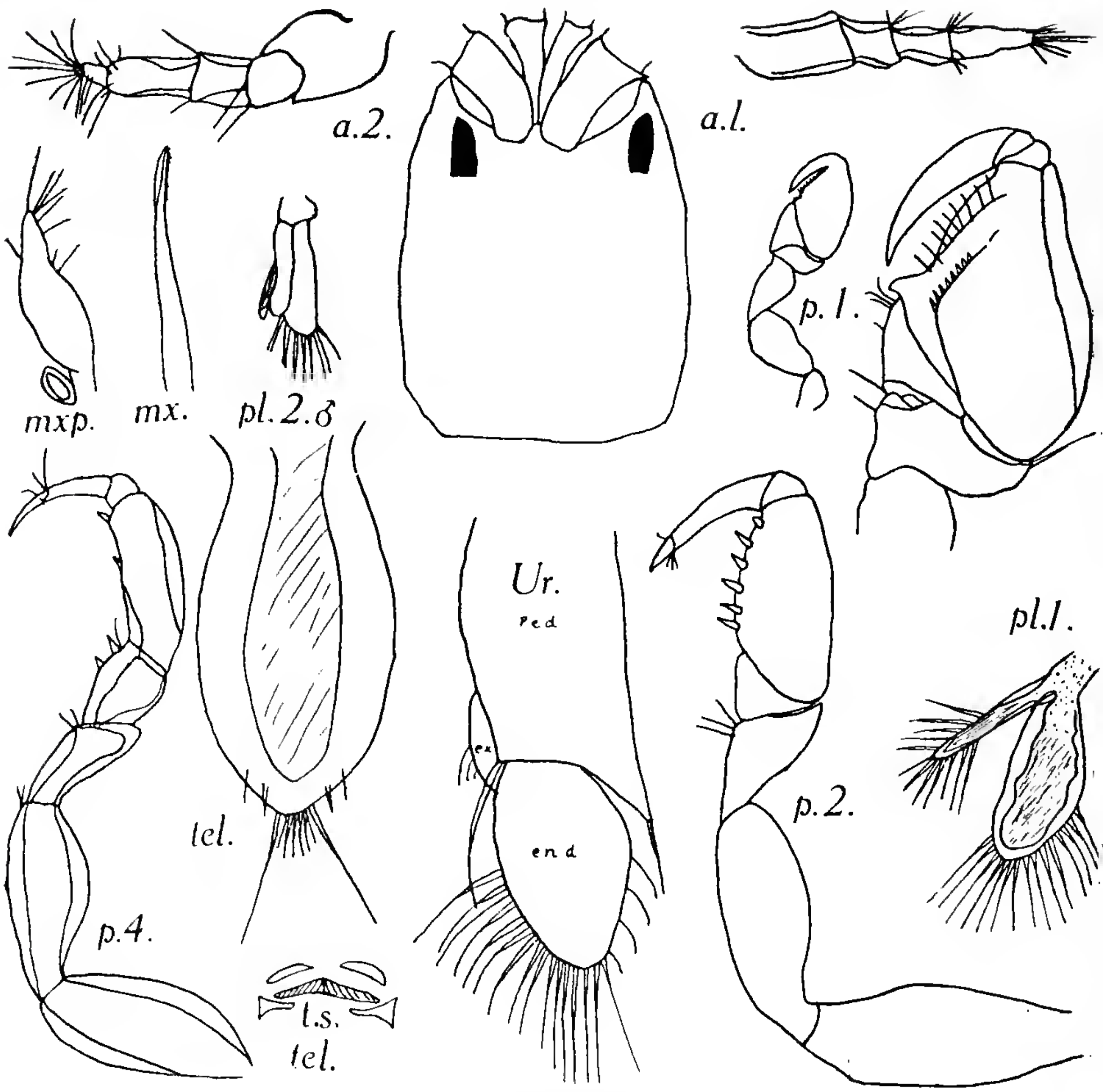
Tail fan: Ends of uropodal endopods coincide with the end of the telson. Exopod arches dorsally over the telson.

Male.

Length: same range as female. Similar to the female except for absence of oostegites and the possession on the second pleopod of a male stylet, which is an elongated rod with a simple rounded apex.

Discussion.

Barnard (1925) lists twenty-four genera of the Anthuridae and gives the specific distinctions of all species known to him. Since his paper eight further species have been described, one of which is ascribed to a new genus, *Notanthura* Monod (1927). The genus here described does not fit in to any of the genera described by Barnard, nor to *Notanthura*. Barnard pointed out that the important generic features were the arrangement of the tail fan, the shape of the telson and the form of the maxillipeds. Apart from the differences in these three features *Cruranthura* differs from all except *Hyssura* Norman and Stebbing 1886, *Colanthura* Richardson 1905 and *Cruregens* Chilton 1881 in the absence of the seventh pereiopod. However it is easily distinguished from the first of these genera. *Hyssura* has multiarticulate flagella on both antennae and the exopods of the uropods do not arch over the telson, the maxilliped is five-segmented, the pleopod is



Text fig 4. *Cruranthura simplicia* sp. nov.

not operculiform and the mouth parts are of the biting type. In all of which features it differs widely from *Cruranthura*. The general arrangement and structure of the antennae of *Cruranthura* are similar to those of *Colanthura*. But the latter genus is distinguished by the following points: the seventh thoracic segment is narrower than those in front and narrower than the abdominal segments; the abdominal segments show no sign of dorsal fusion; the telson is linguiform and appears to be without setae; no tooth defines the palm of the pereiopod in any described species of *Colanthura*. Unfortunately Richardson's description gives no account of the mouth parts. Of all the Anthurid genera *Cruranthura* undoubtedly comes nearest to *Cruregens* Chilton. The maxilliped structure is identical, except that some setae occur along its length in *Cruranthura*, not merely apically. It is possible however that such is the case with *Cruregens* though neither Chilton's nor Barnard's figures show this, and Chilton's description reads "The terminal portions are free, and the ends . . . . are tipped with setae." The structure of pereiopods and antennae are also similar. *Cruranthura* differs from *Cruregens* in the presence of eyes, the subterranean *Cruregens* being without them. The exopods of the uropods in *Cruregens* do not arch over the telson and they are long narrow filaments, whereas in *Cruranthura* they are shorter, broader and lamelliform. Also *Cruregens* shows no signs

of dorsal fusion in the abdomen. The telson, to judge from Chilton's figure, differs also in that it is as wide proximally as more distally, whereas in *Cruranthura* it is a distinctly narrowed proximally.

Of the genera possessing a seventh pereiopod Cruranthura eomes nearest to *Paranthura,* Bate and Westwood 1863, but differs in the form of the maxillipeds, the presence in the latter genus of the eharaeteristic flat flagellum on antenna 2, and differences in the strueture of antenna 1.

Generie features: *Cruranthura* is distinguished then, by the faet that it has eyes, the maxilliped is two-segmented, the uropodal exopod arehes over the telson, the abdominal segments are fused dorsally, and the seventh pereiopod is absent.

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Suborder: VALVIFERA.

Family: **MUNNIDAE**.

MUNNA Boeck (1839).

Munna brevicornis sp. nov.

OCCURRENCE.

July to December; sparingly on algae.

FEMALE.

1·7 mm. in length. Body broad, rather flattened and oval; length twice the breadth. Head broad, its length: breadth ratio equals 1 : 1·5. The anterior margin of the head is straight, deeply notched on each side at insertion of the antennae. The eyes are large, situated on lateral projections of the head.

The first four pereion segments are subequal in length, the first slightly shorter than the others. Thorax wider than the head, each segment to the fourth being wider than the one in front. The last three thoracic segments are shorter and curve backwards at the sides. The lateral margins are all rounded. The pleon is much narrower, somewhat pear-shaped (ob-pyriform), extremity rounded, without denticles but with a few fringing setae.

Appendages: Antennules reach about to the end of the 4th segment of the peduncle of the antennae. Basal segment the broadest, the second is only half as broad at the base, but expands slightly distally, and is covered with scattered setae. The next two segments are subequal and small. Following these are two long segments, the distal of which is the longer. At the extremity is a small segment. There are apical setae and "olfactory filaments."

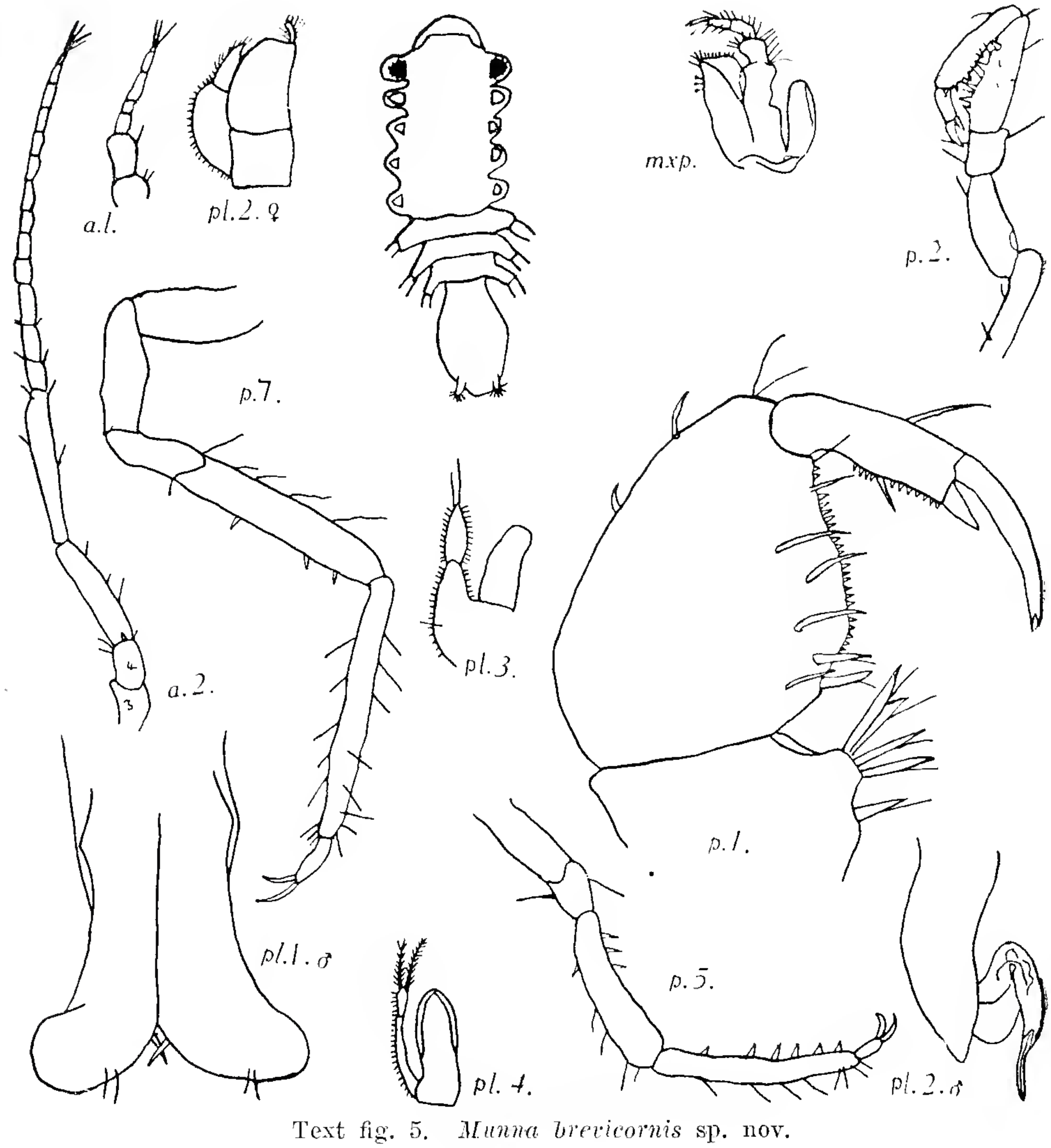
Antennae not as long as the body; the first three segments short and subequal, the succeeding ones long and slender, the more distal longer than the other. Flagellum longer than the peduncle. Mandibles with cutting edge divided from the molar expansion by a deep cleft; palp well-developed. Maxilla 1 of the usual shape, outer lobe the longer and relatively stout, bearing about ten denticulate spines. The inner lobe is almost as long but is more slender; it is widest at a third of the distance from its base, and is armed with three spines terminally. Maxilla 2 of the usual shape with pectinate setae along the margin. Maxillipeds protecting the remainder of the mouth part and being rather lamelliform. From the coxa spring an epipodite and a large basis which is produced at its extremity, the inner side of which is lined by short setae, three of which at the end are stout and spinelike. The ischium of the palp is short. The merus is longer and fringed with setae and expanded distally. Carpus broader than long, propod narrow, expanding slightly at its extremity and curving inward, and is setose. Dactyl two-thirds as long as propod and ends in two stout setae.

Pereiopod 1 with basis long, four times as long as broad; ischium about as long but narrower, merus expands antero-distally where it bears a single seta, a few others occurring on the anterior margin. The carpus is about the same size, but produced on the postero-distal angle which bears five spines, an apical cluster of four and one proximally on the margin. The propod is about as wide, its palmar margin with a convex expansion, fringed by small spinules. Two large spines occur at the base and several long setae over the surface. The dactyl bears a few fine setae and ends in two distinct spines, the outer of which is twice the length of the other. Pereiopod 2 about half as long as the body. The coxa is short but separate from the body; basis long and narrow, with setae on the hind margin and one anteriorly; ischium is similar in shape, not quite as long as the merus and narrower at the base though expanding somewhat at its middle length, with a few distal setae; carpus the same length as the ischium with a few scattered stout setae, mostly on the posterior border; propod shorter than the carpus and narrower, with four spines on the posterior border, and fine setae on the anterior; dactyl short and oblong, with two apical claws and two setae. Pereiopods 3 and 4 similar to the first except that the carpus and propod are elongated. Pereiopods 5-7 similar but considerably longer.

Pleopod 1 modified to form an anal operculum which widens abruptly from its base and is rounded apically where a few setae are present. Pleopod 2 with basal protopod bearing an inner flat branchial plate as the endopod; at its internal distal corner the branchial plate has a plumose seta. Exopod fused at its base with protopod. Its end segment is not quite as long as the basal, and both are fairly short and stout. The distal segment bears two stout apical setae. The whole exopod is fringed with delicate fine setae. Pleopod 3 very similar to pleopod 2 but has no apical seta on

the branchial plate, and the exopod is longer and narrower. Pleopod 4 with an oblong branchial plate free from setae. Exopod longer and still more slender than in pleopod 3, fringed with fine setae, and the second segment tipped with two plumose setae. Pleopod 5. A branchial plate only.

Uropods small, conical with a few setae; inserted somewhat dorsally at the posterior margin of the pleon segments.



Text fig. 5. *Munna brevicornis* sp. nov.

MALE.

Length 1·4 mm. The body is distinctly narrower than in the female; length two and a half times the breadth. The first four pereion segments are subequal in length, the first slightly shorter than the others. The first thoracic segment is wider than the head, the second narrower; the third and fourth are wider than the first. The next three segments are shorter and turn back at the sides as in the female.

Pereiopod 1 similar to that of the female, equally massive, but longer.

Pleopod 1 modified as an accessory sex organ, consisting of two oblong plates fitting close together along the median line, narrow in the middle and wider again at the extremities, turning out and being rounded terminally. The upper surface is produced in a thin plate. A fold on each side distally produces a pair of ducts. On the distal rounded portion there are two setae apically on each side, and one medianly. Pleopod 2 curved and elongate, broader at the base with two apical setae; penial filament apparently two-jointed, one joint directed backwards, the other lying in the opposite direction, curved and ending in a long styliform extremity grooved along one side. A second short round projection lies distally from the penial filament. Otherwise the male is like the female.

From other species *brevicornis* may be distinguished by the relative shortness of the antennae, the shape and armament of the first thoracic appendages, the absence of denticles on the pleon. The posterior three thoracic segments are not so crowded relatively as in other species, the body being relatively elongate. Details of setation and armature on the other legs are also specific.

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4.—THE FAUNA OF THE ALGAL ZONE OF THE SWAN RIVER ESTUARY.

A PRELIMINARY SURVEY OF FRESHWATER BAY WITH NOTES ON THE CHIEF SPECIES.

By

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Read 14th March, 1944.

INTRODUCTION.

The primary aims of this investigation were, firstly to learn the nature of the fauna inhabiting the algae, and secondly to follow the seasonal change in this fauna. From the data gathered various other observations have been made, such as the species density and population density of various algal species.

Adequate ecological study requires a team of workers. A lone worker can hope only to make a general survey of the situation. Especially is this so when, besides collecting and the laborious and time-expending work of separation it is necessaray to identify species which are quite unfamiliar. As a result a number of species have only been identified as far as the genus, and some remain assigned only to the family. However, all those which can be described as dominant have been specifically identified except for an immature Gammarid which occurred at times.

Acknowledgment is due to Professor G. E. Nicholls and to Dr. A. G. Nicholls for advice on literature and aid in other ways; and to Miss A. M. Baird and Mr. G. G. Smith, of the Botany Department for aid in identification of the higher algae.

Collections were made somewhat irregularly, due either to the number of species requiring identification, or to other unavoidable circumstances.

PRELIMINARY SURVEY OF FRESHWATER BAY.

PHYSIOGRAPHY.

Accounts of the Swan River estuary have been given by Somerville (1919) and by Aurousseau and Budge (1921). It need only be added that the main area of investigation was situated in Freshwater Bay at the part marked "C" in the map given by Somerville (*op. cit.* p. 17). The rocky bottom under the high cliffs at this point provides an admirable substratum for the algae.

PHYSICAL CONDITIONS.

The Swan estuary differs in type from those upon which a fairly abundant literature exists (Alexander 1936; Bassindale 1938; Milne 1940, etc.). Along the coast in this region there is practically no tide; as a result there is no daily alteration of fresh and salt water in the estuary, nor are there areas of mudflats daily exposed as is the case in tidal estuaries. There

is, however, a marked seasonal variation in salinity (Serventy 1938). In summer, conditions in the estuary are marine. In winter, the water is greatly diluted and after heavy rains becomes quite fresh at least in shallow water near the banks. This dilution is greatest during July and August.

During part of the year there is a regular daily rise and fall in the waters of the estuary, generally of about four to six inches. This appears to be due, not so much to tidal influence, but to the regular alternation of land and sea breezes. An easterly (land) breeze drives the waters of the adjacent ocean away from land, depressing the level of waters along the coast and consequently in the drowned valley of the estuary. A westerly (sea) breeze piles water against the coast and raises the water level. If the westerly continues for several days, as may happen during a storm, the level of water is raised several feet. Similarly when an easterly continues for an abnormal period, the water level may drop a few feet and as a result expose some of the algal beds which otherwise are not out of water.

The area under investigation is under direct illumination from the sun from early morning till late afternoon, when the high cliffs shut off the direct rays of the sun.

No measurements of temperature were taken, but, as was to be expected, in depths of only a few inches the water was considerably warmer than in deeper water, if there had been practically no water movement for some time and the sun was particularly hot.

The currents in the estuary are practically confined to the deeper channels. Shallow areas such as the one under consideration are more influenced by the surface drift produced by winds. Though normally inconsiderable, waves of up to two feet may be raised during strong winds, thus laying the shallows open to some battering.

There is always a considerable amount of organic matter and soil in the water, but usually the bottom can be seen at several feet depth. However, after heavy rains greatly increased quantities of material occur suspended in the water and it may be impossible to see the bottom even at a depth of 1 ft. 6in. Photosynthesis in the algal zone must be considerably impeded during such periods.

ALGAL ZONE.

The rock bottom on which the algae occurs is a ledge of shallow depth along the bank, extending outwards for a width of 7ft. to 16ft. Most of the algae occurs from surface level to a depth of 5ft., though ocasionally patches were found at 7ft.

METHODS.

The method of collection consisted simply of plucking the algae from the substratum and transferring to a collecting jar. In the case of larger algae, such as *Cystophyllum muricatum* it was sometimes necessary to cut off only part of the stem or only branches. At first the transference of material was made under water with a control jar of water to ascertain whether there was any free-swimming population to influence results. Later trials, however, showed that no significant loss occurred if the algae were lifted out of the water and then transferred. As this method was more rapid and more easily accomplished it was adopted.

ESTIMATION OF POPULATION.

Although the importance of the algal fauna has long been recognised and such phrases as "among sea-weed" frequently occur in records, few studies of the fauna of aquatic vegetation have been made. Those that have been made are concerned almost entirely with fresh water plants (Ward, 1896; Moore, 1913; Richardson, 1921; Percival & Whitehead, 1929; Krecker, 1939), usually with flowering plants. Descriptions of the algal zones of the sea have rarely been accompanied by data as to the small members of the communities on and among the algae. The record is mostly of the dominant animals, usually Molluscs, occurring on the same substratum as the algae and sometimes passing on to the vegetation. (Flattely & Walton 1922; Colman, 1933; Kitching, 1935; Bright, 1938; Stephenson & Bright, 1938; Bokenham, 1938; Eyre, 1939; Stephenson & Day, 1940). A method for the quantitative analysis of the fauna of aquatic vegetation is wanting. Moore (1913) used the general terms "abundant" and "scarce." Bokenham (1938) used "Dominant," "Plentiful" and "Present." Richardson (1921) made a quantitative count of the upper nine inches of aquatic plants. The count was based on the animals washed off the plants collected from a definite area. Other workers (Needham, 1928, 1929; Pate, 1932) have failed to differentiate between the animals of the plants and those of the underlying substratum, except in the case of the two authors mentioned next.

Krecker (1939) working on fresh-water phanerogams took as a basis the population per ten linear feet of plant. He conducted a plant to plant examination. The only alga investigated in the Swan estuary which lends itself to such treatment is *Cystophyllum muricatum*, which attains lengths of up to seven feet. But the majority of the algae are relatively short, occurring as more or less branching filaments or intertwining strands densely crowded together. The broad flat *Ulva lactuca* provides a third type.

Colman (1940) working on the fauna of the intertidal sea-weeds, used the number of animals per unit weight of sea-weed. The method adopted in the present research was to calculate the fauna per 100 c.c. of the alga measured by displacement of water. As few, if any, of the animals present used the algae as food, but rather as a substratum it was considered that the space occupied by the alga was of more significance than the weight, since the volume bears a constant relationship to the surface of the plant (though admittedly the relationship varies to a degree from plant to plant according to irregularities of shape) whereas the weight is not a function of the surface, since it varies with the density. The displacement method adopted is also advantageous in being rapid.

By this means a picture was gained not only of the algal fauna as a whole, but enabled comparison between different algae.

Algae.

The dominant species of algae in the estuary are:—

Cystophyllum muricatum	*Enteromorpha compressa*
Chaetomorpha aera	*Ectocarpus confervoides*
Cladophora penicillata	*Ulva lactuca*

Besides these, others occur, usually as isolated clumps amongst the others and may sometimes have been included amongst collections. (For example. other species of *Enteromorpha* may have been included amongst *E. compressa.*) These secondary species include:—

Asperococcus sp.	*Chaetomorpha nitidula*
Calothamnium sp.	*Caulerpa cylindracea*
Enteromorpha prolifera.	*Gracilaria confervoides*
Enteromorpha intestinalis	*Monospora australis*
Enteromorpha claphrata	*Polysiphonia mollis*
Enteromorpha plumosa	*Zoobotrium pelucides*

Some of these are abundant elsewhere in the estuary (*G. confervoides*) but do not occur in quantity in the area investigated.

Diatoms.

Some colonial diatoms were present on the algae throughout the year. Three periods of particular abundance were noted. These occurred in March, May and October. From the nature of their surfaces *Cystophyllum* and *Cladophora* provided the best substratum for these, while *Ulva* was practically free from diatoms. From May to late July diatoms were fairly abundant but were very scarce in August and September.

No identification was attempted beyond the genus. The following are the genera present at the three peak periods. Except from May to July the amount of diatoms rather rapidly fell away from the peak.

March.	May.	October.
Frustulia (*Navicula*)	*Coscinodiscus*	*Synedra*
Pleurosigma	*Rhizosolenia*	*Bacillaria*
Gammatophora	*Gammatophora*	*Melosira*
Lycmophora	*Melosira*	
Melosira	*Nitzschia*	
Striatella	*Lycmophora*	
Asterionella (?)		

The genera are listed in order of relative abundance. It is notable that the October increase was due almost entirely to *Synedra*. By November *Bacillaria* and *Melosira* had disappeared and *Coscinodiscus* was sparingly present.

FAUNA.

Here is given a list of the fauna as identified for the purpose of this investigation. Thus Gammarid spp. includes two or three species of which one representative only was found and cannot be regarded as a true member of the algal fauna.

Protozoa
- No record kept. Maximum abundance in April.

Hydrozoa
- *Campanularia verticillata* (?) (Linn).

Turbellaria
- *Leptoplana* spp.

Nemathelminthes
- *Nematoda* spp.

Polychaeta
- *Nereis oxypoda* Marenzeller
- *Nereis albanyensis* Augener
- *Ceratonereis erythraeensis* Fauvel.
- Small Nereids
- *Odontosyllis fulgarans* Claparede
- Spionid. sp.

Oligochaeta
- Microdrilids.

Polyzoa
- Polyzoan sp.

Tanaidacea
- *Tanais cavolinii* Milne-Edwards.
- *Paratanais* sp.

Harpacticoida
- *Ameira minor* Thompson & Scott.
- *Amphiascoides intermixtus* (Willey).
- *Amphiascopsis sexsetatus* (Monard).
- *Amphiascus* sp.
- *Dactylopusia tisboides* Claus
- *Ectinsosoma propinquum* T. & Scott.
- *Harpacticus gracilis* Claus
- *Idyella exigua* Sars
- *Mesamphiascus normani* (Sars)
- *Mesochra parva* J. M. Thomson
- *Parathalestris* sp.
- *Perissocope* sp. (?)
- *Pseudothalestris pygmaea* T. Scott.
- *Tegastes* sp.
- *Tisbe furcata* Baird
- *Tisbe graciloides* Sars
- *Tisbe tenera* Sars
- *Zaus* sp. (?)

Calanoidea
- *Gladioferens imparipes* J. M. Thomson.

Ostracoda
- *Xestolebris aurantia* Baird.
- *Cytherid* spp.

Isopoda
- *Cruranthura simplicia* J. M. Thomson.
- *Munna brevicornis* J. M. Thomson.

Amphipoda
- *Caprella penantis* Leach
- *Caprella scaura* Templeton
- *Corophium minor* J. M. Thomson
- *Corophium* sp.
- *Erichthonius pugnax* Dana
- Gammarid spp.
- *Melita* sp.
- *Pallasea* sp. (?)
- *Talorchestia* sp.

Caridea
- *Leander intermedius* Stimpson

Brachyura
- *Cyclograpsus audouinii* Milne-Edwards.
- *Halicarcinus australis* (Haswell)

Arachnida
- *Litarachna* sp.

Insecta
- Chironomid (?) larvae

Mollusca
- *Modiolus* sp.
- *Rissoa* sp.

Ascidacea
- *Ascidea malaca* (Traust.)

Chaetognatha
- *Sagitta* sp.

Analysis of Collections.

Appended at the end of this paper is a table (Table 1) setting out the monthly mean results. The quantities are expressed, as explained under "Estimation of population," in terms of the number of animals per amount of algae displacing 100 c.c. of water. The total number of animals in any column then represents the population density per 100 c.c. for that type of algae.

From the table it is evident that no species of alga was present during all 10 months, although *Enteromorpha* was completely absent only in August. The following list shows the species of alga present from month to month and their relative abundance.

(a)—abundant; (b)—well distributed; (c)—isolated stands.

March—*Cystophyllum* (a), *Enteromorpha* (a), *Ulva* (b).

April—*Cystophyllum* (a), *Enteromorpha* (a).

May—*Cystophyllum* (a), *Enteromorpha* (a).

June—*Cystophyllum* (b), *Enteromorpha* (a), *Ulva* (a).

July—*Cystophyllum* (c), *Enteromorpha* (b), *Ulva* (a), *Chaetomorpha* (c).

August—*Ulva* (a), *Chaetomorpha* (b).

September—*Cystophyllum* (c), *Enteromorpha* (b), *Cladophora* (c).

October—*Enteromorpha* (c), *Cladophora* (c), *Ectocarpus* (a).

November—*Enteromorpha* (a), *Cladophora* (a), *Ectocarpus* (a).

December—*Enteromorpha* (c), *Cladophora* (a), *Ectocarpus* (c), *Ulva* (c).

Animal Distribution.

From March to September *Cystophyllum muricatum* provided the most favoured habitat for the algal fauna. From October to December *Ectocarpus confervoides* was favoured as long as it was thriving, but in December when it was decaying *Cladophora penicillata* became the chief habitat. *Ulva* at all times provided the least utilised substratum, being most densely inhabited in March when the fronds were of great size and much convoluted. There can be little doubt but that it is the character of the plant that causes the differences rather than environmental conditions. It is noticeable that *Cystophyllum muricatum, Cladophora penicillata* and *Ectocarpus confervoides* provided the best substrata for the colonial diatoms.

Seasonal Changes.

Almost assuredly associated with the change in salinity is the change in the species making up the algal communities. No species was recorded in all ten months. *Tanais cavolinii,* while absent only in October, was repre-

sented by immature specimens only during August, September and November. The following were the dominant species (numerically) from month to month:—

March—*Tanais cavolinii. Caprella penantis.*
April—*Caprella penantis; Tanais cavolinii.*
May—*Harpacticus gracilis.*
June.—*Erichthonius pugnax; Melita* sp. (Immature).
July—*Caprella scaura; Tanais cavolinii.*
August—*Gladioferens imparipes.*
September—*Gladioferens imparipes.*
October—*Mesochra parva; Gladioferens imparipes.*
November—*Mesochra parva; Gladioferens imparipes.*
December.—*Harpacticus gracilis; Tisbe tenera.*

The population density of the algal zone fell from March to August and then rose again. (See text fig. 1.)

The number of species present also dropped from 33 in March to six in September, rising again to 25 in December.

SPECIES DENSITY.

Following Hesse, Allee, Schmidt (1937), "Species Density" is taken to mean the number of species present in unit area or unit volume. The figures are given at the bottom of Tables 1 and 2. It will be seen that although *Cystophyllum* had the greatest population density, in March and June its species density was not as great as that of *Enteromorpha,* and in April and May there was no significant difference between the two. The highest species density is 25, recorded for *Cladophora* in December. *Enteromorpha* follows with 22 in March. Like the population density, the species density fell from March to August and September and then rose again. The lowest species density recorded was 1 (*Ulva* in August, and *Enteromorpha* in September). Species density does not necessarily correspond with the population density. Thus in March *Cystophyllum* had the greatest population density, but the lowest species density.

Again, although two species of alga may have similar species densities, the species making up the community are not necessarily the same. Thus in July *Enteromorpha* and *Ulva* had species densities of 13 and 12 respectively but had only five species in common. The apparent preference for one alga or another is doubtless extremely complex in its causation; all the factors that influence environmental distribution probably play a part, food, competition with other species, vulnerability to attack and so on.

VARIATIONS WITH DEPTH.

Apart from the collections summarised in Table 1, on three occasions separate collections were made to gain an idea of distribution by depth. The results are shown in Table 2. The four inches nearest the surface are least densely inhabited, particularly where open to buffeting by the wind-driven waves. In positions sheltered by large rocks the top few inches are more thickly populated. Most species were taken between four inches and two

feet depth. But the population density varied in its maximum from deeper than two feet to shallower, probably according to the physical conditions at the particular time. A point to be noted is that in November, *Gladioferens imparipes* was present in large numbers below a depth of two feet, but absent entirely above; whereas *Mesochra parva* was present in large numbers in the surface layers, but few in numbers below two feet.

BIOTIC INFLUENCE FROM OUTSIDE THE COMMUNITY.

It has been mentioned earlier that certain of the species recorded in these collections are more properly regarded as only occasional intruders into the algal association. Such are Gammarid spp. *Cyclograpsus audouinii, Modiolus sp., Sagitta sp.* Besides these there are occasional intruders which are not recorded in collections but whose presence was noted. This group includes both aquatic and non-aquatic creatures.

Aquatic intruders.

Trochus sp. Abundant on rocks above and below water level, and occasionally found amongst the algae. Also on the rocks occur *Balanus nigrescens* and *Balanus amphitrite* which possibly influence the abundance of the algae. *Sphaeroma quoyana* with its attendant commensal *Iais pubescens* (var. *longistylis*) burrows into the sandstone which forms the substratum for the algae. Whether it has any influence on the algal fauna above is unknown. Similar remarks apply to various Gammarids, Polychaets and Turbellarians found on the rock, together with various Isopods.

Hippocampus tuberculatus Castelnau has been taken in this weed area. Dunker (1910) reports *Trachyrramphus brevicaudis* Castelnau from the Swan estuary also, and this species may also occur amongst the algae.

The blue Serrated Swimming crab *Scylla serrata* has also been observed amongst the algae. Swarms of little fish periodically appear, and these were particularly abundant during September-October. The common "jellyfish," *Aurelia aurita* is sometimes driven in large numbers among the algae, with what effect, if any, upon the algal fauna is problematical.

Extra-aquatic intruders.

These generally appear when the water is particularly low, exposing the algal beds to the air. Some of the birds also pick through the weeds in shallow water. The following have been observed apparently feeding on or among the algae or the Molluscs on the rocks beneath.

Phalacrocorax atra.
Phalacrocorax varius.
Phalacrocorax carbo.
Microcarbo melanoleucus.
Pisobia minuta
Tringoides hypoleucus.
Larus novae-hollandiae.

When the algae are exposed, numbers of ants, flies, wasps, spiders, land isopods and beetles (e.g., *Ophodinus* sp.) make their way thither, retreating again as the water rises. Most of the algal fauna doubtless retreats as the water level falls, but some at least remain in the damp weed.

NOTES ON THE CHIEF SPECIES.

The notes presented below are mainly of an ecologic and systematic nature. No detailed account of any species is given.

Leptoplana spp.

A few specimens were definitely identified as *Leptoplana,* but it is possible that other genera are included under this heading. These animals were much more common on the rocky substratum, and occurred on the algae mostly when they were covered in diatoms and were in an old and semi-decaying state.

Ceratonereis erythraeensis Fauvel 1919 and *Nereis oxypoda* Marenzeller 1879.

Monro (1938) has recorded these species from the Swan estuary, and Augener (1913) named ? *Nereis (Ceratonereis) aequisetis* which Monro says may be the former species. These were the largest and most common of the nereids found on the algae.

Nereis albanyensis Augener 1913.

A few specimens were obtained in August. The species has been recorded by Augener from Albany and Fremantle. Except for an occasional small specimen, Nereids were absent from March to October.

Tanais cavolinii Milne-Edwards, 1828.

This is probably a cosmopolitan species. It has been recorded from the Atlantic Coast of North America, Bermuda, Greenland, West Coast of Norway, British Isles, Western France, Azores, Mediterranean. It usually occurs in shallow water (1ft. to 6ft.) among algae. It has also been recorded from oysters, on *Balanus,* on *Pinna,* and sponges.

T. cavolinii is tubicolous, though it leaves its tube quite regularly in search of food and crawls slowly over the algae. The tube is of mucin, to which little bits of algae and other detritus are joined. On several occasions Nematodes were found in the same tube. The tubes are usually twice as long as the animal, but may be smaller or larger.

Although as far as ascertained not previously recorded from the southern hemisphere, there is little doubt that the species recorded is *T. cavolinii.* It agrees perfectly with Sars' (1899) description of *tomentosus* (synonymy, see Dollfuss, 1897) and with Richardson's (1905) description.

The numbers of *T. cavolinii* were greatest in March, and the proportion of ovigerous females was also greatest at this time (33%). Numbers fell off rapidly till June, presumably as a result of the lowering of salinity. A temporary increase occurred in early June, ovigerous females being taken for the first time since the end of April. However, by the middle of July the species was again very scarce and was not recorded at all in October. No females were found from the middle of July to the beginning of September. The few specimens found in November were all immature.

There seems little doubt that optimum conditions in the estuary for *T. cavolinii* occur during the summer, probably before March. Males were more numerous than females from March through the winter, but females were present in greater numbers than the males in December.

Dactylopusia tisboides Claus 1863.

This species was never very common, but was taken in every sample from March to July. Distribution is very wide: recorded from Woods Hole, Franz Josef Land, Greenland, Coast of Norway, Kiel Bay, British Isles, France, Mediterranean, Red Sea, Kerguelen, Western Australia.

Ectinosoma propinquum T. and A. Scott, 1896.

Also not common but taken from March to June. Distribution: Scotland, Franz Josef Land, Coast of Norway, Ceylon.

Harpacticus gracilis Claus, 1863.

It is possible that some specimens attributed to this species are referable to another as each individual was not checked. But several times during the year a proportion of the specimens were examined and on each occasion proved to be *H. gracilis*. The limbs correspond perfectly in structure with the drawings of Monard (1928). Distribution includes the North Sea, Mediterranean, Black Sea, Chilka Lake, Suez Canal, Atlantic Coast of North America, Kerguelen.

The species was evidently decreasing in March, was poorly represented in April but underwent a huge increase in May to decrease in collections throughout June. It was absent from August to October. In November a few specimens occurred, but by December a tremendous increase had again taken place.

Mesochra parva J. M. Thomson.

This was recorded in sparing numbers throughout the year until October when it swarmed in the shallower waters, while *Gladioferens imparipes* was predominant rather deeper. A check of the collection has shown that while the October-November increase included only *M. parva* earlier in the year (March-June) a few of the specimens recorded as *M. parva* are referable to another species, and are tentatively assigned to *M. pygmaea* (Claus) with which they agree most closely. This latter was represented by only a few specimens among the total. No sign of *M. parva* was found in December, its place being taken, apparently, by *Harpacticus gracilis.*

It is noteworthy that the proportion of males to females was 1 : 1.6 in October but was only 1 : 6.8 in November. About 50% of the females were ovigerous.

Perissocope sp. (?) This is a very uncertain identification, being first made from Wilson's key (1932), but imperfectly confirmed.

Tisbe spp.

Three species of *Tisbe* were identified, none being particularly numerous except *T. tenera* in December. *T. tenera* Sars and *T. furcata* Baird (1850) were found and a third species somewhat questioningly identified as *T. graciloides* Sars. These latter corresponded fairly well with Sars' figures especially in the detail of the first antennae.

The three species were present in greatest numbers in December. Their numbers during the rest of the year were low, though in July they were among the more conspicuous members of the fauna, since all species had either disappeared or were present in small numbers. Ovigerous females and immature specimens were common in December.

Distribution:—*T. tenera*: coast of Norway, English Channel, Roscoff, Suez Canal, Nicobar Is.

T. furcata: Alaska, New Zealand, Pacific Islands, Ceylon, Chilka Lake, Red Sea, Mediterranean, North Atlantic, Baltic, Nicobar Is., Maldive Is.

T. graciloides: West coast of Norway.

Gladioferens imparipes J. M. Thomson.

The genus is a southern hemisphere one closely related to *Boekella*. Its recorded distribution is from Western Australia through South Australia and New South Wales to New Zealand, generally in brackish waters.

G. imparipes first appeared in July when the river was becoming fresh, and slowly increased in numbers to become a dominant form in August, and reached its greatest numbers at the beginning of November, though at this time it was no longer found in the shallowest water as formerly but only amongst the algae at depths greater than 2 feet. By December only a few specimens remained.

Males and females were present in approximately equal numbers till the November increase, when females were more than twice as abundant as males. The proportion of ovigerous females was rather steady at about ¼ of the total.

Xestolebris aurantia Baird 1850.

The peculiarities of this genus left little doubt as to the generic identity of this form. On the basis of its close agreement with Sars (1921) description of *aurantia* it has been assigned to that species. Distribution: The British Isles, Holland, Baltic, Norway.

Cruranthura simplicia J. M. Thomson.

This was taken in few numbers in June, July and September, on each occasion on *Cystophyllum* only.

Munna brevicornis J. M. Thomson.

Taken in July, October, November and December. Numbers were small, but several ovigerous females were taken, together with males and immature specimens.

Caprella penantis Leach 1814 and *Caprella scaura* Templeton 1836.

These two forms were common among the algae and have been recorded together in the Tables as *Caprella* spp. Their variability with growth and sexual maturity was so great that identification was difficult. From March to May *C. penantis* formed the greater proportion of the catch. Those caught in July were entirely *C. scaura*.

Mayer (1912) in *Fauna Sudwest-Australiens* records *Metaproto novae-hollandiae, Monoliopus agilis* and *Caprella aequilibra* also from the Swan river. No adult specimens of these species were taken. It is possible however that the young of *C. aequilibra* are included amongst the recorded immature forms, since the young of *C. scaura* and *C. penantis* develop to a considerable size before the frontal spine and other armature appears.

The Caprellids were among the dominant members of the fauna during March and April. Their numbers were reduced by the end of May, and they were present in but few numbers in June. They experienced a temporary increase in July and then disappeared. Despite the onset of summer conditions they had not reappeared in collections by 12th of December.

Distribution:—*C. penantis* (*C. acutifrons*) has been recorded from Geraldton and the Swan River, W.A., South Australia, New South Wales, Mediterranean and North Sea.

C. scaura from the Swan and at Bunbury, W.A., South Australia, New South Wales, Mediterranean, Rio de Janeiro, Mauritius, Japan, California.

Corophium minor J. M. Thomson.

It was taken from March to July, and then reappeared in November. It was taken in greatest numbers in late March. In December another larger species of *Corophium* was taken. It has not been identified and is recorded here as *Corophium* sp.

Erichthonius pugnax Dana 1852.

Chilton (1922) and others have considered that this and other recorded species of *Erichthonius* are to be referred to one species *E. brasiliensis* as different growth stages. However all the specimens collected which ranged from immature forms to ovigerous females and larger males were in close agreement with descriptions of *E. pugnax*. One large male seemed more in accord with *E. macrodactylus*.

The species is tubicolous, inhabiting tubes built on the algae. These tubes are very similar to those of *Tanais carolinii* but with a greater proportion of sand utilised. The species was found only during June and July, but during the former month was one of the dominant species, at least as far as numbers are concerned. As far as I can ascertain this is the first record of the genus from Australia.

Distribution:—New Zealand, Sooloo Sea.

Melita sp.

Practically all the specimens recorded under this heading are immature specimens. However unless a great change occurs in proportion of parts such as the very short inner ramus of the third uropod and other character-

istics there can be little doubt that it is a *Melita*.. The generic distinctions are in agreement with those given for *Melita* by Stebbing (1906) and by Barnard (1941).

Leander intermedius Stimpson, 1860.

Serventy (1938) states that he found *Palaemonetes australis*, Dakin (1915) only, in the Swan estuary. I am not aware whether any of his specimens came from Freshwater Bay, but he does mention taking some in Crawley Bay, some way upstream. The nature of Crawley Bay differs from that of the area investigated in being predominantly sandy with scattered pieces of rock and continuing out as a shallow shelf much further than is the case in Freshwater Bay. All the specimens taken amongst the algae were *Leander intermedius*. Each specimen was dissected to make certain. In each case the mandible bore a distinct large palp, the absence of which distinguishes *Palaemonetes* from *Leander*. Besides those recorded in Table 1 extra specimens were taken from the algal area. (Kemp (1925) gives an excellent key and descriptions.) All proved to be *L. intermedius;* the specific characters were definitely those of intermedius, not of the marine *serenus*.

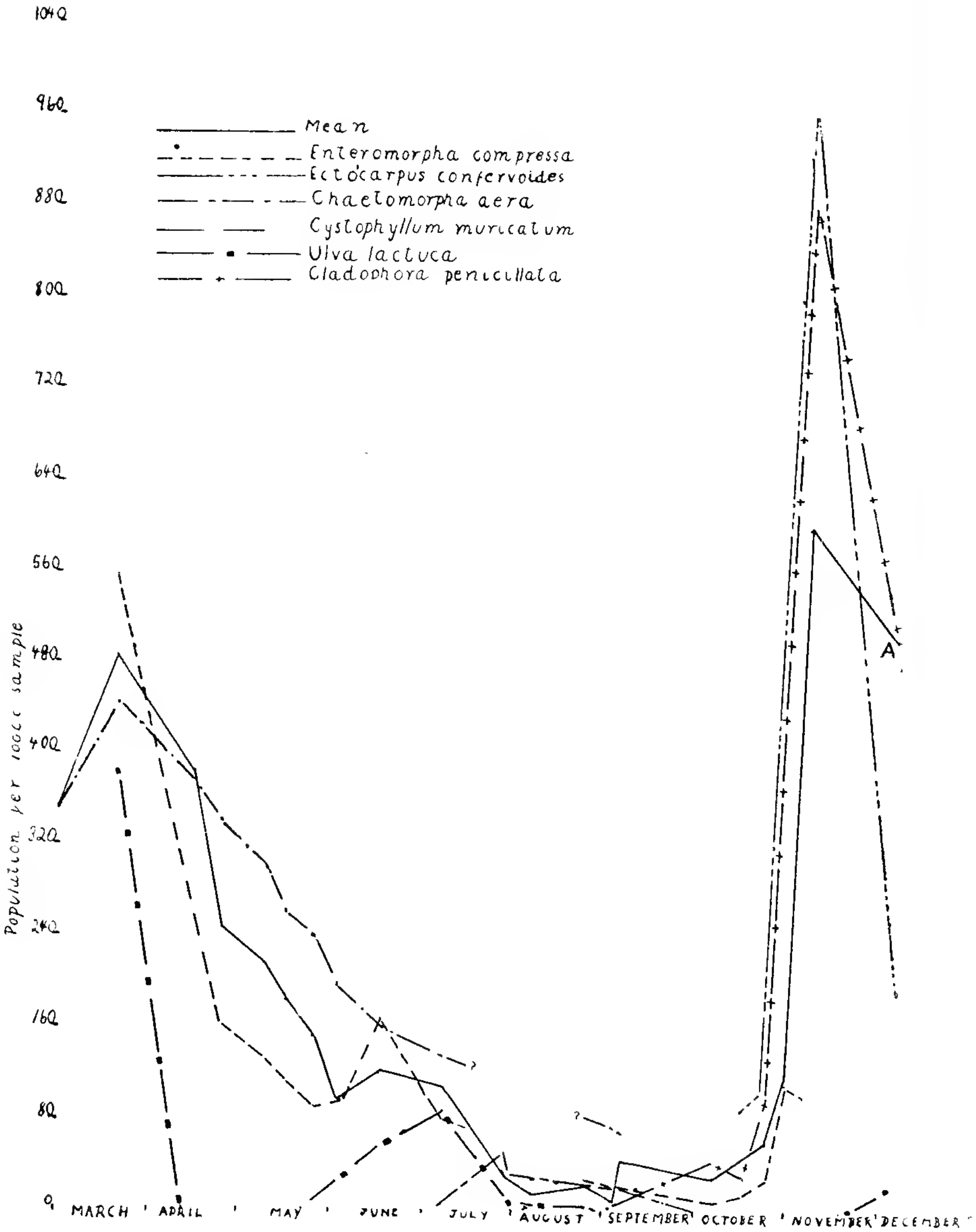
It was noted that a shrimp occurred on the shallow sandy portion of the bay just down-stream from the rock-algae area. Specimens of these were taken, and proved to lack a palp to the mandible and were identified as *Palaemonetes australis*.

It seems then that both these shrimps occur in the estuary in different habitats, *L. intermedius* among the algae, and *P. australis* in the sandy shallows. Distribution: South Australia, Tasmania, Cockburn Sound.

SUMMARY.

The fauna occurring in six species of algae was investigated. The species of algae varied in abundance and none was present in all ten months of the survey. Some 52 species of animals were recorded as members of the algal community. These occurred in varying abundance at different times of the year. The maximum number of species occurring in any month was 33, the minimum six. Population density and species density are shown for each species of alga. Population density, species density, amount of diatoms present, and abundance of algae were all lowest in August-September. The dominant species in each month are listed. The nature of the species present changed as the salinity dropped during heavy winter rains. As summer returned the summer members of the fauna returned with the increasing salinity, *Caprella* spp. being the only species common in late summer collections which had not returned by December. It was found that the top four inches or so of the algae were not favoured, but most species were taken between four inches and two feet. A list of occasional intruders into the algal community is given. Added are ecologic and systematic notes on the chief species. A graph (text fig. 1) summarises the variation in population density. Besides the figures for each species of alga an estimated mean is given which is the average reading of the different algae present at the time, their relative abundance being ignored except at the point A. The reading at this point represents the figure for *Cladophora pencillata* only since this was in vast abundance, whereas the other species recorded at this time were present in extremely small widely-scattered clumps. The reading for *Cladophora* thus gives a much more accurate picture of the algal fauna.

It will be noticed that two crops of *Ulva lactuca* occur during the year. *Cystophyllum muricatum* was not collected in August, and in September only a small specimen was found, after which none occurred. The dates of appearance and disappearance of other algae can be seen from the graph. A tremendous increase in animal population is indicated in November. It can be seen from the graph that the summer population is several times greater than that in mid-winter.



Text fig 1: Variation in population density. March-December, 1943.

TABLE I.

MONTHLY VARIATION IN POPULATION & SPECIES DENSITY FOR EACH ALGA.

SPECIES.	*Cystophyllum muricatum.*							*Enteromorpha compressa.*										*Ulva lactuca.*					*Chaetomorpha aera.*		*Cladophora penicillata.*				*Ectocarpus confervoides.*		
	March.	April.	May.	June.	July.	August.	September.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	March.	June.	July.	August.	December.	July.	August.	September.	October.	November.	December.	October.	November.	December.
Campanularia penicillata								1																							
Leptoplana spp.	18	8	12	2				4	2										5	1											
Nematoda spp.			10	2	10			22		12	1							9	2									2			
Ceratonereis erythraeensis	18	1		11			11	21										5	1									24		3	
Nereis oxypoda	10							14								8											3	8		5	
Nereis albanyensis																										2					
Small Nereids					2			6			2								3					2		1		34	2	8	
Hesione sp.																												1			
Odontosyllis fulgarans					2																		1								
Splonid sp.		2													2											2					
Autolytus sp.		1																													
Microdrilids				2				3																							
Polyzoa sp.			4	30							3								1												
Ameira minor	2	1		3				2	1		3							9	2							6					
Amphiascoides intermixtus			6							1																					
Amphiascopsis sexsetatus										1																					
Amphiascus sp.								20										8										1			
Dactylopusia tisboides	4		16		5			18	1	1	9							2		3											
Ectinosoma propinquum	8		4	5						1	8	3						2	4				14								
Harpacticus gracilis	93	6	108	7	5			16	4	29	35					8	10	51		3			4				2	140		2	120
Idyella exigua											6							1													
Mesamphiascus normani											1	1																			
Mesochra parva			5		4			21							16	72		1		1				1	3	57	836		76	623	
Parathalestris sp.				3								3																			
Perissocope sp.			11							4	2																				
Pseudothalestris pygmaea										4	3																				
Tegastes sp.										3								1													
Tisbe furcata											2	3					10	1		27		8						20			
Tisbe gracilloides											1	7						2		17											
Tisbe tenera			2		3			6			7	18						1				18						83			10
Tisbe sp. (Immature)																												127			
Zaus sp. ?																		1													
Harpacticoids (Immature)											9															1			2		
Gladioferens imparipes					2		71					6		20	1					1				16	9	1		2	32	298	
Copepod nauplii												3																			
Xestolebris aurantia															1	16										1	1	1		3	
Cytherid sp.											2	3			1			1								1	5	1	1		
Cirriped nauplii															1																
Tanais carolinii	246	102	1	17	11		11	52	13	26	5	1						18	4	3				6			2	9			22
Paratanais sp.									1																						
Cruranthura simplicia				1	1		4																								
Munna brevicornis												3			2											11	7			2	
Caprella spp.	6	242	2	9	50			124	93	18	1							71					16								
Corophium minor	23			3	3			2	5	8								10									6			4	
Corophium sp.																											4				
Erichthonius pugnax				55	9														1					4							
Gammarid spp.		2	1	1				1																				1			
Melita sp.	14	2		1	17			6		3	66	9					8		5	8						7	28	9			
Pallasea sp. ?	1																														
Talorchestia sp.	2									1																					
Leander intermedius	1							10																							
Cyclograpsus audouinii	3																														
Halicarcinus australis	1	2																													
Litarachna sp.												9				2											2	8		6	
Chironomid larvae		4			2		3	4	4							1		5					4	4				3			
Modiolus sp.								1							1			1		7	6										
Lamellibranch sp.																												1			
Rissoa sp.									1			3																1			
Gastropod eggs			M																												
Ascidea malaca			2		5																										
Botryllus sp.					M																										
Sagitta sp.																												1			
Fish eggs																			1									1			
Total Population	150	379	185	160	169	...	109	377	159	142	166	69	....	20	55	107	58	195	28	75	6	28	37	33	12	96	879	418	114	951	182
Species Density	16	12	13	17	17	....	5	22	11	14	19	13	....	1	8	6	3	21	11	12	1	3	5	6	2	11	8	25	6	10	3

M = Masses.

TABLE 2.

VARIATION IN POPULATION WITH DEPTH.

Species.	March.				July.		November.	
	Enteromorpha compressa.				*Cystophyllum muricatum*		*Ectocarpus confervoides.*	
	Open.		Sheltered.					
	Above 4 in.	4 in. to 1 ft. 6in.	1 ft. 6 in. to 2 ft. 6 in.	Above 4 in.	Above 1 ft.	Below 1 ft.	Above 1 ft.	Below 1 ft.
Leptoplana spp.	....	3	1	5	....	....	....	....
Nematoda spp.	32	8	10	....	....	12	....	....
Ceratonereis erythraeensis	....	19	4	5	....	....	2	2
Nereis oxypoda	....	....	....	....	....	....	3	3
Small Nereids	....	3	....	....	1	3	....	....
Odontosyllis fulgarans	....	....	....	....	....	2	....	....
Spionids	....	7	....	2	....	....	....	....
Ameira minor	....	16	....	8	....	....	....	....
Amphiascus sp.	....	10	....	9	....	....	....	....
Dactylopusia tisboides	....	9	....	2	....	4	....	....
Harpacticus gracilis	....	8	64	46	2	5	....	3
Mesochra parva	....	....	....	....	....	5	804	33
Parathalestris sp.	....	....	....	....	2	5	....	....
Tegastes sp.	....	....	1	....	....	....	....	....
Tisbe graciloides	....	....	....	5	....	....	....	....
Tisbe tenera	....	....	....	....	....	3	....	....
Zaus sp. ?	....	....	3	1	....	....	....	....
Gladioferens imparipes	....	....	....	....	....	3	....	298
Xestolebris aurantia	....	....	....	....	....	....	2	2
Cytherid sp.	....	....	....	1	....	....	3	2
Tanais cavolinii	20	33	169	18	3	39	....	1
Cruranthura simplicia	....	....	....	....	1	4	....	....
Munna brevicornis	....	....	....	....	....	....	....	2
Caprella spp.	43	23	4	84	15	47	....	....
Corophium minor	....	1	24	12	....	3	....	4
Erichthonius pugnax	....	....	....	....	....	9	....	....
Melita sp.	....	3	8	....	....	15	....	....
Chironomid larvae	....	2	....	1	....	2	1	....
Litarachna	....	....	....	....	....	....	6	....
Modiolus sp.	....	2	....	1	....	....	....	....
Halicarcinus australis	....	....	....	1	....	....	....	....
Ascidea malaca	....	....	....	....	....	6	....	....
Botryllus sp.	....	....	....	....	....	M	....	....
Total Population	95	147	284	201	24	167	821	350
Species Density	3	16	8	16	6	18	7	10

M = Masses.

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No. 5—INVESTIGATION OF SOME PHOSPHATIC NODULES FROM DANDARAGAN, WESTERN AUSTRALIA.*

BY KEITH R. MILES, D.Sc., F.G.S.

Read, 9th May, 1944.

INTRODUCTION.

The work described in the following pages was carried out consequent upon field investigations of the various phosphatic deposits of the Dandaragan District, conducted by Mr. R. S. Matheson of the Geological Survey of Western Australia during the period May, 1941, to December, 1943.

Specimens used in this investigation included a number of nodules recently collected by Mr. Matheson from pit CG on Cook's Deposit (Upper Phosphate Bed)† located on Melbourne Loc. 704, and nodules (surface boulders) collected from the vicinity of pit BD on Minyulo Deposit (Upper Phosphate Bed) on Melbourne Loc. 284, Dandaragan. Several specimens of phosphatised wood collected by Mr. W. G. Campbell in 1906 from the South-East corner of Melbourne Loc. 957 about five miles north of the principal phosphate deposits on what is now known as "Summer Hill" Deposit (Lower Phosphate Bed), (site of the original find of phosphate rock in the Dandaragan District), were also sectioned and examined.

THE NODULES.

Description.

Four nodules from the Cook's Deposit were sectioned. They were marked A, B, C, and D respectively. It was seen that when broken they ranged from greyish yellow to brownish yellow in colour. The writer was informed by Mr. Matheson that unfortunately most of these nodules were darker in colour and were presumably slightly more ferruginous in composition than the average fresh nodules from Cook's.

The nodules from Minyulo Deposit, being surface boulders were rather weathered, and in places cellular, and coloured a dark brown except where whitened by adhering chalk. One fairly fresh dense and compact-looking specimen was sectioned and marked E. Several other specimens contained partly enclosed fragments of phosphatised wood.

Mega.—On megascopic examination all nodules were found to consist essentially of detrital quartz grains cemented in a fine granular greyish to fawn coloured groundmass. The quartz grains vary in size from fragments up to 5 mm. in diameter down to grains of microscopic size ($<0 \cdot 02$ mm.). The average grain size of the quartz varies considerably in different specimens examined, *e.g.*, nodule A contains a much higher proportion of comparatively large grains (>1 mm. diam.) than all other specimens and has an average grain size of about $0 \cdot 37$ mm. In nodules B, C, and D the quartz is more even in grain and has an average diameter of approximately $0 \cdot 18$ mm. Nodule E contains many large grains, though proportionally less than A, and has an average of about $0 \cdot 26$ mm. diameter. The grains range from sub-angular to rounded.

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†Site of the recent find of Mesozoic reptile remains. See Teichert, C., and Matheson, R. S. (6)

In addition to the quartz, nodule A contains a number of clearly visible sub-angular fragments of creamy white colour showing cleavage faces characteristic of *felspar*. These reach up to 3 mm. in diameter.

Broken faces of nodules C, D, and E occasionally contain small cellular surfaces stained yellow with iron oxide.

Micro.—Apart from the detrital quartz and occasional felspar visible in hand specimens as already mentioned, other essential constituents which can be recognised under the microscope are grains of *glauconite* and *iron ore* enclosed in a matrix or cement of light yellow-brown coloured amorphous isotropic material with refractive index distinctly > quartz (about $1 \cdot 6$), which is identified as *collophanite* (or *collophane*). In addition, in many of the slices there are small fragments of phosphatised wood in which the original cell structure is often perfectly preserved but which are now composed entirely of collophanite. The microscopic appearance of typical thin slices is shown in Text fig. 1.

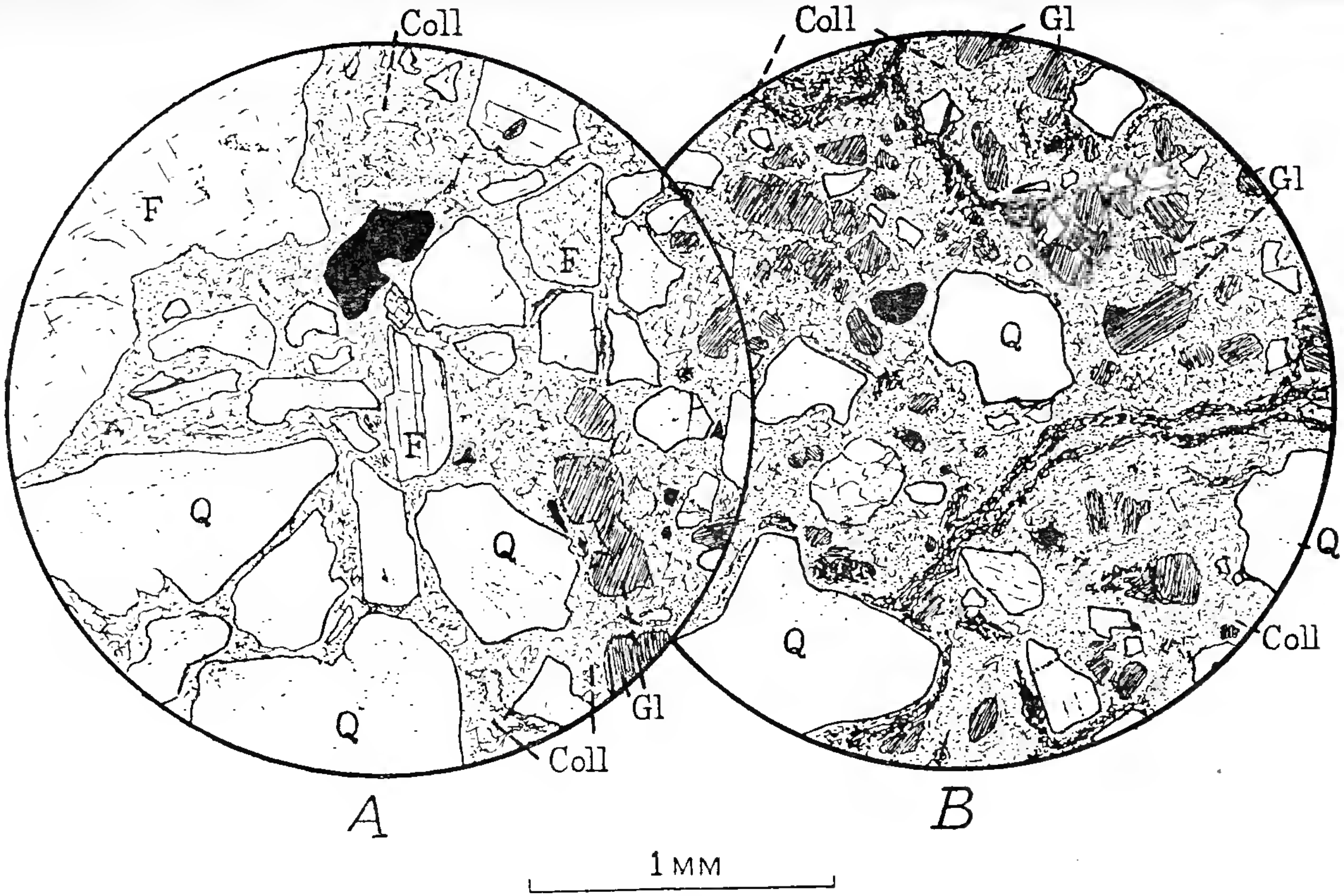
The quartz grains are usually clear and vary from sub-angular and occasionally sharply angular for the smaller grains, to distinctly rounded for the larger grains. A rapid microscopic survey suggests that in nodules containing quartz grains of the same average grain size the degree of rounding is about the same.

Detrital felspar grains were found to be most abundant in nodule A, (Text fig. 1A) but were present in all specimens examined. They consist mainly of *microcline* showing typical cross hatched twinning, but a few grains of untwinned *orthoclase* were recognised. In nodule A both microcline and orthoclase occasionally showed incipient kaolinisation and alteration to pale green chlorite. In nodules B, C, D, and E and to a lesser extent in A, many of the felspar grains showed considerable alteration and replacement along cleavages, to a yellow-green mineral displaying aggregate polarization. which is indistinguishable from the glauconite.

Glauconite is present in varying amount in all specimens. It occurs in irregular shaped rounded pellets or granules ranging in colour from yellow-green to olive green and in size from about $0 \cdot 03$ mm. up to approximately $0 \cdot 4$ mm. diameter (see text fig. 1A and B). These have refractive indices ranging from slightly less than to distinctly greater than that of the enclosing collophanite. They show aggregate polarization, the interference colours being almost entirely masked by the absorption colour of the mineral. No interference figure was obtainable. In several of the nodules, especially in D and E. some of the glauconite showed partial alteration to limonite. Occasionally glauconite granules were seen to enclose minute fragments of black opaque iron ore. The glauconite granules usually occur in scattered groups surrounded by collophanite.

The iron ore occurs in two forms—in sporadically scattered, usually rounded (detrital) black opaque grains ranging from about $0 \cdot 02$ mm. to $0 \cdot 20$ mm. in diameter, and as red opaque filling material found in places rimming grains of glauconite, quartz and black iron ore, and occurring in occasional veinlets traversing the slices.

Examination of the black opaque grains obtained from crushed nodule material showed that some of these were distinctly magnetic and many others non-magnetic and on crushing yield a red powder—thus it is probably mostly *hematite* with some *magnetite*—nearly all grains being altered in some degree at least, to *limonite*.



Text fig. 1.

PHOSPHATE NODULES FROM DANDARAGAN.

A. Nodule A, Cook's Deposit. Showing detrital fragments of quartz (Q), felspar (F), with several grains of glauconite (Gl) and iron ore—magnetite or hematite (black opaque)—cemented in a matrix of collophanite (Coll) The felspar grain at top left is portion of a large crystal of microline.

B. Nodule D, Cook's Deposit. Glauconite (Gl) is much more abundant in this specimen. No felspar is visible in the field. The collophanite (Coll) matrix is traversed by several vein-like lines which are cloudy and opaque from alteration, and which are slightly stained by limonite.

The red opaque material is *limonite*, obviously a product of weathering and decomposition of other iron bearing minerals in the nodules, *viz.*, glauconite and magnetite-hematite. Although usually concentrated in seams or veinlets, in some of the more weathered specimens the limonite also occurs as a very finely divided material staining the collophanite matrix in irregular patches. In such cases estimation of the relative quantity of limonite present becomes rather difficult.

The collophanite cement where fresh is pale fawn to light yellow-brown coloured and completely isotropic. It is for the most part massive and structureless except where it has replaced fragments of woody tissue or where, particularly surrounding quartz grains and vugs in nodule A, it displays distinct colloform structures. Under high powers apparently clear collophanite is seen to be filled by microscopic inclusions in which limonite, glauconite and gas bubbles can be recognised. Under high powers the colloform areas in nodule A and to a lesser extent in B, D, and E, reveal crusts with banded subradiating structure, of a pale grey coloured very weakly birefringent mineral. This has straight extinction. Columns of crusts are sometimes length slow and sometimes length fast so that though some of this may be collophanite it is probably in part the secondary *dahllite*, or *francolite*, or a related mineral.

In the more weathered portions of specimens examined the collophanite matrix is usually altered to a red-grey cloudy opaque material often heavily stained with limonite.

Accessory detrital minerals noted were zircon in rare broken grains in nodules E, A, and B and one or two grains of rutile and pink garnet in A. It may be noted here that no calcium carbonate minerals and no iron or aluminium phosphates were seen in any of the slices examined.

Relative Composition.—To determine the approximate mineral composition of the phosphate nodules micrometric analyses were made of four specimens—A, B, and C from Cook's Deposit and nodule E from Minyulo. The results of these analyses are set out in the following table :—

TABLE 1.

APPROXIMATE MINERAL CONTENT OF PHOSPHATE NODULES.

Mineral.	Cook's Deposit.				Minyulo Deposit.
	Nodule A.	Nodule B.	Nodule C.	Average.	Nodule E.
	%*	%	%	%	%
Quartz	55½	24½	17	32½	42
Collophanite ...	31½	45½	61½	46	32
Glauconite ...	4½	20	13	12½	15
Iron Ore	3½	7	6	5½	9
Felspar	5	3	2½	3½	2
	100	100	100	100	100

* All percentages are by weight.

In carrying out the micrometric measurements, the author probably tended to overestimate the iron ore, especially limonite—particularly in the more weathered specimens B, C, and E—since he was inclined to class brownish, iron-stained glauconite granules as wholly limonite at times, and it is considered that the figures for iron ore shown above may be a little high.

No attempt was made to differentiate between the magnetite-hematite and the limonite which in most specimens are in the ratio of between 1 : 2 and 1 : 3. In calculating the relative weights the following specific gravities were used ; quartz 2·65, collophanite 2·7, glauconite 2·6, iron ores 4·5, felspar 2·55. Phosphatised wood fragments were included with the matrix when measuring the collophanite content. Felspar was estimated as microcline. The accessory minerals were neglected.

From Table 1 it can be seen that the relative proportions of the three main constituents quartz, collophanite and glauconite vary considerably between wide limits, though quartz and collophanite appear to occur in inverse ratio one with the other. The fact that the total glauconite, iron ore and felspar content is appreciable in all specimens examined, indicates that notable amounts of iron oxide and alumina are present in the nodules.

In Column 4 of Table 1 is given the average composition of nodules A, B, and C from Cook's Deposit. Then assuming the following approximate compositions for the minerals ; glauconite SiO_2 52%, Fe_2O_3 20%, Al_2O_3 10%, MgO 3% (1) and K_2O 3% (2) ; iron ore Fe_2O_3 85% ; and felspar SiO_2 65%, Al_2O_3 18%, K_2O 16% (3) ; the Cook's Deposit nodules have the approximate partial chemical composition shown in Column 1 of Table II.

No attempt has been made to estimate the CaO and P_2O_5 content, etc., as the exact composition of collophanite (essentially hydrous calcium phosphate with variable amounts of calcium carbonate, fluoride and sulphate, etc.). is not known.

The above figures bear interesting comparison with the results of a complete chemical analysis of a composite sample of nodules from Cook's Deposit made at the Government Chemical Laboratory shown in Column 2 of the following table :—

TABLE II.

ANALYSIS OF NODULES.

	1.	2.
	%	%
SiO_2	40·6	46·02
Al_2O_3	1·8	2·36
Fe_2O_3	7·1	3·38
MnO	....	0·02
MgO	0·36	0·42
CaO	....	23·62
K_2O	0·85	0·80
P_2O_5	....	16·66
CO_2	....	1·70
H_2O+	....	1·29
H_2O-	....	0·98
SO_3 (water soluble)	....	0·04
SO_3 (acid soluble)	....	0·15
Cl	....	0·01
F	....	Present
Loss on Ignition	....	0·41
	....	98·09

1. Micrometric analysis showing partial composition of average of three nodules from Cook's Deposit. All percentages shown are by weight. (Anal. K. R. Miles).
2. Chemical Analysis of a composite sample of nodules from Cook's Deposit. (Anal. H. P. Rowledge).

Comparison of these figures tends to bear out the impression that the specimens examined by the author contain appreciably more iron oxide (probably in the form of iron ores) than the average nodules from Cook's Deposit but it is interesting to note that probably *all* iron oxide, alumina, potash and magnesia shown in the chemical analysis of the composite sample *can be accounted for by the glauconite. iron ore and felspar in the nodules themselves.*

THE PHOSPHATISED WOOD.

An examination was made of thin slices of three specimens of phosphatised wood. Some of this material was figured and described by Simpson in 1912 (4). The "wood" itself is now completely replaced by phosphatic material optically and microscopically indistinguishable from the collophanite (which Simpson regarded as fluorapatite) matrix of the nodules described above except that in most cases the minute structures of the original woody tissue have been perfectly preserved. The wood has been identified as a Mesozoic conifer classed as *Cedroxylon* (4).

Of interest in the present investigations is the fact that all the specimens examined are abundantly riddled with tunnels and pipes filled with phosphatic material which appears identical in composition with the phosphatic nodules already described. These tunnels are considered to have been made by boring organisms in the original wood. Specimens of wood examined ranged from $1\frac{1}{2}$ inches to 3 inches in diameter and were up to $3\frac{1}{2}$ inches long. The borer holes are up to about 0·35 inch in diameter and often run the full length of the wood specimen.

Under the microscope the material filling these borer holes is seen to consist essentially of detrital quartz and felspar, and abundant glauconite with rare scattered fragments of black opaque iron ore (? magnetite) set in a matrix of collophanite similar to that found in the phosphate nodules. Some secondary limonite was seen in the more weathered specimens but was completely absent from the freshest specimen examined.

The quartz in this material is fine and even grained, seldom more than 0·5 mm. in diameter. The felspar includes fragments of microcline, orthoclase and twinned plagioclase, probably oligoclase. Detrital zircon is a rare accessory. In addition to the above, the borders of several borer holes were marked by clusters of tiny spherical brown bodies. These have already been noted by Simpson (*op. cit.*) and considered to be the fossil excreta of wood boring beetles.

No attempt was made to measure the relative proportions of the components of the filling material in these borer holes, but from a visual inspection the writer considers that although the iron ore content is probably less than that of nodule A described above, the average glauconite content is at least as high as in nodule E and is probably between 15 to 20 per cent. The proportion of quartz to felspar is probably about 10 . 1.

It is interesting to note therefore that even in specimens of phosphatised wood, which from Dandaragan is a source of high grade phosphate, there is a certain amount of deleterious material (iron oxide and alumina) present in the form of minerals occurring as filling material for the numerous borer holes within the wood.

ORIGIN OF THE NODULES.

In his original description of the Dandaragan phosphate deposits in 1907 W. D. Campbell (5) stated that the phosphate nodules were "coprolites," presumably accumulations of animal excreta, bones and teeth. Simpson's subsequent investigations in 1912 (4) showed that the so-called bones and teeth were in reality fossil wood, and it was not until December, 1943, that undoubted bone fragments were recognised and identified from these deposits (6). Simpson seems to have retained the term "coprolite" for the nodules, however, and this name apparently remained unchallenged until the last few years. As a result of field investigations in the Dandaragan District in 1941 Matheson in an as yet unpublished report (7) expressed the view that the nodules are of inorganic origin and quoted the supporting opinion of Teichert that the use of the term ' coprolite" bed should be discontinued.

Evidence available from the present investigation is, in the writer's opinion, strongly in favour of the view that these nodules have been formed by inorganic chemical action. The nodules are composed of grains of quartz, glauconite, felspar and iron ore—all normal components of the enclosing greensand—which are cemented together by phosphatic material to form separate rounded, relatively compact bodies lying within beds of more or less consolidated glauconite, quartz, felspar, etc., grains intermixed with some chalk. This suggests that nodules have been formed by deposition of calcium phosphate (collophanite) around grains of quartz, glauconite, etc., within the original greensand, and that gradual accumulation about these primary centres of deposition has resulted in larger and larger concretions. It is probable that in many cases original interstitial chalk has been replaced by the cementing calcium phosphate, whilst the frequent presence of phosphatised wood fragments within the nodules themselves suggests that wood fragments have often formed the nuclei for the growth of nodules.

No clue as to the source of the original phosphoric acid responsible for the precipitation of the collophanite was afforded by this microscopical investigation of the nodules, though it may be hazarded that this material was probably dissolved out of original organic remains either from within the enclosing beds or from an adjacent, possibly higher horizon.

SUMMARY AND CONCLUSIONS.

A number of specimens of phosphatic nodules from Cook's Deposit, and one from Minyulo Deposit, Dandaragan, have been examined microscopically and their mineral content figured and described. Unfortunately the material available for examination from both deposits is probably not truly representative but is slightly more ferruginous than the average nodules.

Micrometric analyses were made to determine the relative proportions of the essential minerals present, *viz.*, quartz, collophanite, glauconite, iron ore and felspar, in several specimens, and the results tabulated. All specimens contained appreciable quantities of glauconite, iron ore and felspar.

Taking the average mineral composition of specimens from Cook's Deposit, the partial chemical composition was calculated. These figures were compared with those of a complete chemical analysis of a composite sample of nodules from Cook's Deposit, and they showed tolerably good agreement.

As a result of this investigation it can be said that most if not all of the iron oxide and alumina obtained from chemical analyses of coarser fractions from sizing tests of Dandaragan phosphate rock occur within the nodules

themselves, as the minerals glauconite, magnetite, hematite, or limonite, and felspar, and not in any outside coating material. No calcium carbonate in crystalline form was recognised during microscopic examination of the nodules though it is possible that a little may be present as a decomposition product of the collophanite. A certain amount of calcium carbonate in the form of chalk is present as a coating on the nodules.

A number of specimens of phosphatised wood (high grade phosphate) from Dandaragan were also examined microscopically. All specimens contained borer holes filled with lower grade phosphatic material similar in mineral composition to the phosphate nodules, *i.e.*, containing *inter alia* a certain amount of iron oxide and alumina as glauconite, iron ore and felspar.

The mineral composition and microstructure of the nodules point clearly to their inorganic origin and they are believed to have formed by precipitation of calcium phosphate about mineral grains in the original greensand. Phosphatised wood fragments have often provided nuclei for the accretion of phosphatic material and the growth of nodules.

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THE CHEMISTRY AND THE CHEMICAL EXPLOITATION OF WESTERN AUSTRALIAN PLANTS

PRESIDENTIAL ADDRESS, 1944.

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CONTENTS.

I. INTRODUCTION.

Investigations of plants which are concerned directly or indirectly with their chemical composition are carried out by a variety of workers, including the chemist, plant physiologist, pharmacologist and agricultural chemist. In all such work, however specialised, collaboration with other scientific workers is essential, more particularly with the botanist, for incorrect identification and naming of species invariably leads to much unnecessary labour. The researches of these workers are never directed towards painting a complete picture of the chemical composition of a plant, but are normally aimed at the isolation of a pure product of some scientific or medicinal value or the identification of some toxic substance. It is perhaps fortunate that this is so because of the difficulties which arise in such investigations.

Such difficulties as are inherent in the variety, complexity and often the instability of the substances being handled, as well as the inaccuracy of many quantitative methods of analysis, are readily appreciated by the chemist. The magnitude of the work, however, is increased considerably by seasonal or even diurnal variation in the composition of plants, by variation in different parts of an individual plant and by variation due to

changes in climate, soil and cultivation. To these must be added the problems associated with the occurrence of physiological forms, or variants, of an individual species.

The term physiological form is applied to morphologically indistinguishable plants which are known to exhibit constant differences in their chemical composition, which differentiate sharply between them. Many such examples are known in the Australian flora, particularly amongst the oil-bearing plants examined by Baker and Smith, formerly economic botanist and economist chemist respectively of the Sydney Technological Museum, and by Penfold, the present curator and economic chemist of the same institution. Physiological forms occur in *Melaleuca uncinata* R. Br. (p. 86), *Eucalyptus campaspe* S. Moore and possibly in *Duboisia Hopwoodii* (F. Muell.) F. Muell. (p. 94).

The importance of the occurrence of such variants lies in the facts that, firstly, essential though it is in any phytochemical work, correct botanical identification does not necessarily tell the full story of the chemical composition of a plant; secondly, the results of the chemical examination of a plant cannot necessarily be applied to an apparently identical plant growing in other districts, regions or countries; and thirdly, the existence of variants may be of considerable importance if commercial exploitation of a plant is to be undertaken.

Provided allowance is made for the possible existence of physiological forms and for variations due to climate, soil and cultivation, a knowledge of the flora of botanically related countries is of value in any phytochemical problem. While, at the present time, it may not be possible to explain the origin of the Australian flora, it is apparent that certain elements of it have originated in pre-existing floras which have become widely distributed (1). Firstly, there is an element of southern derivation, either antarctic or sub-antarctic, which is shared with New Zealand, South America and South Africa. Secondly, there is a paleotropic element which, originating in Asia, has migrated not only to Australia through India, Malaya and the East Indies, but has also travelled down the east coast of Africa. We may therefore look to the floras of the countries surrounding the Indian Ocean, of Melanesia and New Zealand and of South America for information and suggestions concerning many of our own plants. To these two elements must be added a third, an Australian element, which is most richly developed in the stable environment of South Western Australia.

Much information concerning the chemistry of many indigenous and some introduced plants in this State is contained in scientific publications of South Africa and India and there is also a wealth of suggestion in the folk-lore of the native races of these two countries and of the natives of East Africa as well. In the Eastern States of Australia, the chemical investigation of plants is being pursued in many institutions and the accumulation of knowledge of the practices of the aborigines normally proceeds with reasonable speed. It is regrettable that in Western Australia so little chemical work has been done up to the present, not only on the elements of our flora which are common to other countries, but perhaps more especially on those plants which are almost restricted to this part of the world. It is also unfortunate that there does not appear to have been any sustained effort made to build up a knowledge of the foods, medicinal substances, etc., which are used by our own native tribes in the different parts of the State.

It is not possible, in a review such as this, to adopt a purely chemical basis for discussion of the topics dealt with and the subject matter has therefore been divided into such sections as essential oils, resins and gums, tannins and kinos, poison plants, dyes and colouring matters, vitamins and medicinal substances.

II. ESSENTIAL OILS.

FAMILY SANTALACEAE.

Sandalwood, the heart wood of *Santalum spicatum* (R.Br.) DC., was first exported from Western Australia in 1845 but it is difficult to fix a date when the oil was first marketed. There was intermittent production of the oil by a number of small distillers about sixty years ago, but it was not until 1921 that systematic and scientifically controlled production of the oil was commenced. Prior to this, the alcohol content of the highest grade oil produced was about 75 per cent., but by 1926 this figure had been increased to 93 to 95 per cent. (2), resulting in the inclusion of the oil in the British Pharmacopoeia. The total santalol content of this oil (that is α — and β —santalol) was only about 45 per cent., but since then, while the high percentage of total alcohols has been maintained, the santalol content has been increased to 60 to 65 per cent. The nature of the remaining alcohols in the oil of *S. spicatum* is not known and the elucidation of their chemical structure is a problem which requires solution (3).

The oil of *S. lanceolatum* R.Br. is also distilled to some extent, on account of its higher laevo-rotation, for blending with the oil of *S. spicatum*. It has been shown (4) to contain the primary sesquiterpene alcohol lanceol.

FAMILY MYRTACEAE.

The oils of many of the species of *Eucalyptus* occurring in the Eastern States of Australia have been thoroughly investigated, but, of the 140 to 150 species known in Western Australia, less than 40 have been examined and not all of these in any detail. The oils consist chiefly of terpene and sesquiterpene compounds associated with more or less oxygenated derivatives such as cineole, alcohols, esters, aldehydes, acids, ketones and phenols, or possibly keto-enol compounds which give colours with ferric chloride. The hydrocarbons present are chiefly pinene and phellandrene, generally accompanied by aromadendrene and occasionally by *p*-cymene and terpinene. The alcohols include geraniol, terpineol and eudesmol, and in some cases they make up an appreciable amount of the oil. These species are not as highly evolved as some of those found in the Eastern States and they include such primitive types as *E. calophylla* R.Br. and *E. diversicolor* F. Muell., the oils of which consist largely of terpenes.

Baker and Smith (5) have examined the oils of *E. accedens* W. V. Fitzg., *E. calophylla*, *E. cornuta* Labill., *E. diversicolor*, *E. gomphocephala* DC., *E. Lehmanni* (Preiss.) Schau., *E. longicornis* F. Muell., *E. marginata* Sm., *E. megacarpa* F. Muell., *E. occidentalis* Endl., *E. platypus* Hook., *E. redunca* Schau., *E. rudis* Endl., *E. salmonophloia* F. Muell. and *E. salubris* F. Muell. *E. platypus* (6) has also been examined by Earl, whilst Phillips (7) has investigated the oils of *E. campaspe* and *E. spathulata* Hook. Further species which have been examined include *E. Flocktoniae* Maiden (8), *E. Kesselli* Maiden et Blakely and *E. dundasi* Maiden (9), *E. salmonophloia*

and *E. tetragona* F. Muell. (10), *E. oleosa* F. Muell., *E. eremophila* Maiden and *E. leptopoda* Benth. (11), *E. astringens* Maiden and *E. pyriformis* Turcz. (12), *E. concinna* Maiden et Blakely (13) and *E. erythronema* Turcz. (14). Mr. H. V. Marr (priv. comm.) has made available the following information from investigations carried out by Messrs. Plaimar Ltd.:—*E. uncinata* Turcz. (yield up to 1.4 per cent., cineole content up to 75 per cent.); *E. leptophylla* F. Muell. (yield about 1.2 per cent., 50 to 65 per cent. cineole); *E. Sargenti* Maiden (yield 1.4 per cent., about 60 per cent. cineole); *E. Formanii* C. A. Gardn. (yield about 1 per cent., about 45 per cent. cineole); *E. conglobata* (R. Br.) Maiden, *E. calycogona* Turcz. and *E. incrassata* Labill. give low yields of oil which contain only small amounts of cineole; *E. gracilis* F. Muell. (yield up to 1.3 per cent., 60 to 75 per cent. cineole) and *E. spathulata* which yields up to 1.6 per cent. of oil of which 50 to 65 per cent. is cineole.

Some of these oils are of obvious potential value as sources of medicinal eucalyptus oil. Others of similar value are *E. erythronema, E. leptopoda* and *E. concinna.* The initial cost of collecting leaves and small branches is a limiting factor in the successful exploitation of any oil bearing species and it is therefore essential that reasonably extensive, closely packed areas be available. It is this factor which has prevented the exploitation of some of our better species of *Eucalyptus.* A possible solution of this difficulty has been suggested by Mr. C. A. Gardner, who considers that species like *E. erythronema,* which has largely been cut out from the wheat belt, could be satisfactorily cultivated and could at the same time be made to serve the extremely useful purpose of preventing soil erosion.

Other genera of the family Myrtaceae yield oils which show some general resemblances to those of *Eucalyptus,* notably *Melaleuca* and *Agonis.* There are nearly 100 species of the genus *Melaleuca* in Western Australia, of which only six have been investigated, two of them for their cineole content alone. *M. leucadendron* L. is well known as the source of commercial cajuput oil. *M. uncinata* has been examined in some detail by Penfold (15) and K. E. Murray (16) and many samples have been examined by Plaimar Ltd. (H. V. Marr, priv. comm.). The species exists in at least three physiological forms, one of which grows preferentially around the low margins of lakes from Ballidu to Lake Grace. This form, which is generally arborescent, gives a low yield of oil which consists largely of terpenes and contains little or no cineole. A second form favours higher ground, particularly in granite country, and gives a much higher yield of oil of which from 75 to 85 per cent. is cineole. The third form resembles closely that described by Penfold from New South Wales.

Murray (*loc. cit.*) has also examined the oils of *M. lateriflora* Benth. var. *elliptica* Benth. and *M. rhaphiophylla* Schau. The former contains a high proportion of hydrocarbons and an unidentified phenol; the latter also contains a high proportion of hydrocarbons including α- and γ-terpinene, probably *p*-cymene, sesquiterpenes and an unidentified hydrocarbon, together with the alcohol Δ^1-terpinenol-4 and sesquiterpene alcohols.

The oils of *M. laxiflora* Turcz. and *M. Websteri* S. Moore have been examined by Messrs. Plaimar Ltd. for their cineole content.

The oil of *Calythrix tetragona* Labill. (17) has been investigated by Penfold, Ramage and Simonsen, and shown to consist largely of esters, notably citronellyl formate and the methyl esters of geranic and probably citronellic

acids, together with pinene and citronellol. From the oil of *C. tetragona* var. *A*, Penfold and Simonsen have isolated the ketone calythrone.

The only other genus of this family of which any species has been investigated fully is *Agonis*, *A. flexuosa* (Spreng.) Schau. having been examined by Parry and subsequently by Phillips (7). The oil contains up to 60 per cent. of cineole and shows a close general resemblance to the cineole-containing eucalyptus oils.

A preliminary examination of the oil of *Chamaelaucium uncinatum* Schau. has shown it to consist mainly of terpenes, principally pinene, together with an aldehyde, probably citronellal, alcohols and esters, including amyl acetate.

Further genera of this family are known to produce volatile oils and the following should be worthy of investigation:—*Leptospermum*, *Callistemon*, *Baeckea* and *Darwinia*.

FAMILY RUTACEAE.

The family Rutaceae is also of importance as an oil producer. The well known *Boronia megastigma* Nees is the only member of its genus to be examined chemically, Penfold (18) having shown the presence of β—ionone and an unidentified alcohol as the chief odoriferous constituents, with triacontane, plant sterols and fat as the natural fixatives.

Penfold (19) has also examined the volatile oil of *Geijera linearifolia* (DC.) J.M. Black, the only representative of this genus in this State.

Both the leaf and fruit oils of *Phebalium argenteum* Sm. have been examined by Finlayson (20) and shown to consist mainly of terpenes (principally *d*-limonene) and sesquiterpenes, together with smaller amounts of geraniol, *l*-citronellol and two unidentified sesquiterpene alcohols, esters of valeric and *n*-caproic acids and methylheptyl and methylnonyl ketones. Murray (16) has examined the leaf oil of *P. filifolium* Turcz. and has shown it to consist largely of hydrocarbons with small amounts of esters, alcohols and possibly a phenol. About 32 per cent. of the oil consisted of an unidentified hydrocarbon, $C_{10}H_{16}$, b.p., 159-161°, from which no crystalline derivatives could be obtained. Murray states that the oils of *P. microphyllum* Turcz. and *P. Drummondii* Benth. appear similar to that of *P. filifolium*. The genera *Phebalium* and *Eriostemon* are closely related but, although some Eastern Australian species of *Eriostemon* are known to yield oils of interest, none of the Western Australian species has been examined.

FAMILY LABIATAE.

This family is equally well known on account of its volatile oils. The chemistry of the oils of the introduced plants *Mentha piperita* L., *M. pulegium* L. and *Rosmarinus officinalis* L. has been thoroughly worked out, but little work has been done on indigenous species. Hurst (21) records a private communication from A. R. Penfold that the oil of *Mentha australis* R.Br. consists largely of unidentified ketones, together with some alcohols and esters equivalent to about 12 per cent. of menthol. *M. satureioides* R.Br. (21) is, like *M. australis*, considered toxic to stock and Maiden (22) states that the oil is similar in properties to the oil of *M. pulegium*. Jones and Smith (23) have shown that it contains about 40 per cent. of pulegone as well as 1-menthone, 1-menthol and menthyl acetate.

All the Eastern Australian species of *Prostanthera* are oil bearing but none of the Western Australian species has been investigated. Maiden (22) mentions that *Ocimum sanctum* L. occurs in two varieties, the Northern Australian variety having an odour of anise and the Eastern variety that of cloves.

Family Coniferae.

As in the rest of Australia, the chief Western Australian genus of this family is *Callitris*. Of our seven species, only one (*C. Roei* (Endl.) F. Muell.) has not been examined at all. Baker and Smith (24) have examined the leaf oils and in some cases the fruit oils of *C. Drummondii* (Parlat.) F. Muell., *C. glauca* (R.Br.) Mirb. *C. intratropica* (F. Muell.) R. T. Baker, *C. robusta* (R Br.) Mirb. and *C. verrucosa* (R.Br.) Mirb. Finlayson (25) has also examined the fruit oil of *C. verrucosa* and Murray (16) has examined the leaf oil of *C. Morrisoni* R. T. Baker. The oils consist largely of the terpenes pinene, *d*- and *l*-limonene and dipentene, together with small amounts of alcohols such as geraniol and borneol and their esters with acetic and occasionally butyric acid. The wood of these species is resistant to termite attack and the chemistry of the wood oils warrants further investigation. Baker and Smith showed the presence of the sesquiterpene alcohol guaiol in the wood of most species, particularly *C. intratropica* and Trikojus and White have discussed the chemistry of the constituents of the wood oils (26) and the chemistry of guaiol (27).

The only other coniferous genera in Western Australia are *Podocarpus* and *Actinostrobus*. Baker and Smith (24) distilled the leaves of *P. Drouyniana* F. Muell. without obtaining any oil but from the leaves of *A. pyramidalis* Miq. they obtained a small yield of oil which consisted mainly of *d*-pinene with a small amount of esters. The remaining species of *Actinostrobus* have not been examined. but it is of interest to note that the oleo-resin secreted at the base of the columella of *A. glaucus* C. A. Gardn. MS is used on account of its healing properties.

Other Families.

Marr (28) has shown that *Stirlingia latifolia* (R.Br.) Steud. (Proteaceae) produces an oil which consists almost entirely of acetophenone. Oil of chenopodium is well known for its use as an anthelmintic and Shapter (29) has shown that distillation of *Chenopodium ambrosioides* L. var. *anthelminticum* (L.) A. Gray (Chenopodiaceae) growing in Victoria and New South Wales gives an oil of satisfactory ascaridole content. Local distillation of the plant, however, failed to give a satisfactory yield on one large scale run. *Alyxia buxifolia* R.Br. (Apocynaceae) is well known to bushmen as a cure for dysentery; the sending of a specimen of its oil to America some years ago resulted in a request for several pounds of the material, but no information is available as to its chemical nature. A preliminary empirical examination of the wood oil of *Myoporum serratum* R. Br. (Myoporaceae) has been published by Hill (30). The volatile oil from *M. deserti* A. Cunn. ex Benth. has been shown by Albert (31) to contain a large percentage of an unidentified ketone. The introduced *Foeniculum vulgare* Mill. (Umbelliferae) grows abundantly in parts of the metropolitan area but, although its oil has been thoroughly examined in other parts of the world, no analysis has been made of the local fruit oil. Finally mention

might be made of the pungent, acrid volatile oil, described by Watt and Breyer-Brandwijk (32), which is obtained from *Anagallis arvensis* L. (Primulaceae).

III.—RESINS AND GUMS.

The only resins which have received any detailed attention from a chemical point of view are those of the different species of *Xanthorrhoea*. Herbert (33) has summarised the work done on *X. Preissii* Endl. up to 1920, while Rennie (34) reviewed the results from several species up to 1926. Finlayson (35) has described the results of an investigation of the resin from *X. reflexa* D. A. Herbert, by the method of steam distillation from alkaline solution, while Holloway (36) has compared the melting and decomposition points of the resin from *X. Preissii* with those of the resins of Eastern States species and has studied the effects of extraction of the different resins with a variety of solvents.

Strevens (37) has contributed a series of articles on the technology of the *Xanthorrhoeae* and Steel (38) has described the destructive distillation of the resin on a commercial scale.

A preliminary investigation of the resinous exudate of the turpentine bush of the Kimberley, *Grevillea pyramidalis* A. Cunn. ex R. Br. var. *leucadendron* (R.Br.) C. A. Gardn., has been made by Hill (39, sub. *G. leucadendron*). This exudate is apparently similar to that from *G. viscidula* C. A. Gardn. which is used by the natives, after mixing with ashes, for rubbing into tribal scars for the production of prominent cicatrices. The occasional abundant production of a hard reddish brown resin by *G. striata* R. Br. is recorded by Maiden (22), who also mentions the formation in quantity of a clear yellowish gum-resin on the branchlets of *Bertya Cunninghamii* Planch.

The production of resins by species of the family Convolvulaceae, particularly those of the genera *Ipomoea, Operculina* and *Convolvulus*, is well known. *Ipomoea hederacea* N. J. Jacq. and *Operculina Turpethum* (L.) S. Manso have been used as purgatives on account of their resin content and doubtless other members will be found to contain appreciable amounts of resin. Hurst (21) records that *Ipomoea polymorpha* R. et S. (sub. *I. heterophylla* R. Br.) is suspected of being poisonous in New South Wales, a reputation which might well depend on the presence of resin in the species. The resins produced by our Gymnospermae have received little, if any attention.

No chemical work appears to have been done on any of the gums. All species of *Acacia* produce gum probably of the arabic type, notably *A. microbotrya* Benth. and *A. Farnesiana* Willd., which is the source of Karachi gum from Sind. Maiden (22) mentions the copious production of gum by *Albizzia procera* (Willd.) Benth. and also refers to a high grade product obtainable from *Pittosporum phillyreoides* DC. The Christmas tree, *Nuytsia floribunda* (Labill.) R. Br., sometimes produces a considerable amount of gum in very large tears. A study of these gums, of the seasonal variation in their formation and of the methods used to obtain nearly colourless products, might well lead to the establishment of a profitable minor industry.

The gum-like or gelatinous substances obtainable from seaweeds are becoming increasingly important in many industries. The highly gelatinous nature of *Eucheuma speciosum* J. Ag., the "jelly plant" of Western Aus-

tralia, was commented on as early as 1887 by Maiden, and the alga has been used locally in canning as a substitute for agar. Unfortunately the production of agar from this species does not appear possible since, on thawing the frozen jel, the water does not escape but is almost completely reabsorbed. The seaweed itself, however, could be utilised in industry in washed and bleached form since it requires only about fifteen minutes boiling to effect complete disintegration and solution as compared with the eight to ten hours needed by the *Gelidium* and *Gracilaria* species commonly used to make agar. Longer boiling of *Eucheuma speciosum* leads to rapid loss of gelatinising properties. The investigation of Eastern States seaweeds is being carried out by the C.S.I.R. (40) and there is need of similar work on Western Australian species, particularly those occurring from Carnarvon or Geraldton southwards.

IV. TANNINS AND KINOS.

A reasonably complete account of the tannin resources of Australia has been compiled through the efforts of numerous workers. The greater part of our information on Western Australian tanning materials was obtained as a result of a programme of work commenced in the Forest Products Laboratory of the Commonwealth Institute of Science and Industry in Perth and completed in the laboratories of the Forest Products Division of the C.S.I.R. in Melbourne. The main results of these and some few other investigations were published by Coghill (41) and by the Forests Department of Western Australia (42). Additional work was done by Maiden (22), Smith (43), Mann (44) and Baker and Smith (24). The principal genera covered in this work are *Acacia, Eucalyptus, Callitris* and *Banksia,* but representatives of numerous other genera are also included.

The production of tannin extracts was investigated by the C.S.I.R. in a pilot plant at the Engineering School of the University of Western Australia. Many possible raw materials were examined and, in particular, much work was done on karri bark which is available in quantity as a mill waste product. This extract, however, is not a suitable tanning material. The plant was taken over in 1932 by Industrial Extracts Ltd. and this company is now producing a very satisfactory extract from the wandoo, *Eucalyptus redunca* Schau. var. *elata* Benth. Some interesting comparisons of this extract with other commercial extracts have been published by Pound and Quinn (45).

Little work has been done on the chemistry of these tannins. Rennie (34) has briefly summarised the work which has been done on the tannins associated with the kinos of Eastern States species of *Eucalyptus* and Phillips (46), in an account of the kino of *E. calophylla*, has reviewed the chemistry of its tannin and has critically examined the work of McGookin and Heilbron (47). Blockley, Spiers and Beverley (48) have examined the wandoo extract which they consider to be a mixture of pyrogallol and catechol tannins, the former predominating.

V. POISON PLANTS.

Although Western Australia occupies an unenviable position in possessing more than her fair share of Australia's poison plants, little attention has been paid to the chemical nature of the toxic principles of these plants and such studies offer an almost unlimited field of research for the chemist.

(a) GLYCOSIDES.

(i) *Cyanogenetic Glycosides.*

The group of poison plants on which most work has been done is the cyanogenetic group. Such plants are widely distributed geographically and they occur in many families. In Australia Petrie and Finnemore have made great contributions to our knowledge in this field and much work has been done in South Africa and India on plants which are known in Australia. Hydrolysing enzymes are absent in a few species while from others the cyanogenetic glycosides have been isolated and their identity determined.

The following have been shown to be cyanogenetic:—*Acacia Cunninghamii* Hook. (no enzyme), *A. Oswaldi* F. Muell.; *Amaranthus viridis* L.; *Asplenium flabellifolium* Cav.; *Bothriochloa Ewartiana* (Domin.) C. E. Hubbard, *B. intermedia* (R. Br.) A. Camus; *Cardamine dictyosperma* Hook.; *Chenopodium Blackianum* Aellen, *C. carinatum* R. Br., *C. cristatum* (F. Muell.) F. Muell.; *Chloris truncata* R. Br.; *Chrysopogon fallax* S. T. Blake; *Colocasia antiquorum* Schott; *Cynodon dactylon* (L.) Pers.; *Cyperus distans* L.f.; *Dactyloctenium radulans* (R. Br.) Beauv.; *Digitaria sanguinalis* (L.) Scop.; *Dodonaea viscosa* (L.) Jacq.; *Drosera peltata* Sm., *D. gigantea* Lindl.; *Eremophila maculata* F. Muell. (49) and *Eucalyptus cladocalyx* F. Muell. (50), from both of which Finnemore isolated prunasin; *Euphorbia Drummondii* Boiss.; *Flagellaria indica* L.; *Goodia lotifolia* Salisb. (51), from which Finnemore isolated a glucoside of *p*-hydroxybenzaldehyde cyanhydrin; *Heterodendron oleaefolium* Desf., the leaves of which are always cyanogenetic, although Dr. H. W. Bennetts (priv. comm.) does not consider the plant toxic in Western Australia; *Indigofera australis* Willd.; *Ipomoea dissecta* Willd.; *Leptochloa digitata* (R. Br.) Domin.; *Lindsaya linearis* Swartz; *Linum marginale* A. Cunn. ex Planch.; *Lolium perenne* L.; *Lotus australis* Andr., from which Finnemore (52) isolated lotaustralin, the glucoside of methylethylketone cyanhydrin; *Neptunia gracilis* Benth.; *Passiflora foetida* L.; *Pomax umbellata* Soland.; *Poranthera ericoides* Klotzch, *P. microphylla* Brougn.; *Schizoloma ensifolium* J. Sm.; *Sisymbrium orientale* L.; *Sorghum halepense* (L.) Pers.; *S. sudanense* (Piper) Stapf.; *S. verticilliflorum* (Steud.) Stapf.; *Themeda australis* (R. Br.) Stapf.; *Trema amboinensis* (Willd.) Blume; *Trianthema crystallina* Vahl.; *Trifolium repens* L., shown by Finnemore (53) to contain lotaustralin; *Vicia sativa* L.

The following are suspected of being cyanogenetic from post mortem examination but have not so far shown to be so in the laboratory:—*Euphorbia boöphthona* C. A. Gardn., *E. clutioides* (Forst. f.) C. A. Gardn. and *Olax uliginosa* (Klotzsch) Klotzsch.

The additional genera are known to contain cyanogenetic species and might repay investigation:—*Adenia, Aristida, Danthonia, Halorrhagis, Juncus* and *Sporobolus.*

Finnemore has found no evidence of the production of hydrocyanic acid in *Acacia aneura* F. Muell., *A. brachystachya* Benth., *A. Drummondii* Lindl., *A. Farnesiana, A. Graffiana* F. Muell., *A. hakeoides* A. Cunn., *A. ixiophylla* Benth., *A. pentadenia* Lindl., *A. rostellifera* Benth., *A. salicina* Lindl., *A. saligna* Wendl., *A. undulifolia* Fraser, *A. urophylla* Benth.; *Eremophila longifolia* F. Muell., *E. bignoniiflora* F. Muell.; *Bryonopsis laciniosa* (L.) Naud.; *Didiscus glaucifolius* F. Muell. and *Trifolium dubium* Sibth.

Although no toxic principle has been isolated from the Western Australian species of *Macrozamia*, the isolation by Cooper (54) of macrozamin from the Eastern States species *M. spiralis* (R. Br.) Miq. may give a lead in the solution of the wider problem. Macrozamin does not give hydrocyanic acid by hydrolysis with acids, almonds or yeast, but it does so after hydrolysis with alkali followed by acidification. Malloch (55) has examined the outer coat and the endosperm of the seeds of *M. Riedlei* (Gaud.) C. A. Gardn. and has shown that the toxic substance is present in the endosperm. Malloch obtained no evidence of the presence of a saponin, glycoside or alkaloid and suggested that the toxicity might be due to the presence of a toxalbumen.

(ii) *Saponins.*

Saponins are probably as widely distributed as the cyanogenetic glycosides and they are of considerable importance not only on account of their toxic properties but also because of their value as emulsifying agents.

Ewart (56) has isolated a powerfully haemolytic saponin from *Atalaya hemiglauca* (F. Muell.) F. Muell. ex Benth., the whitewood of our North West, which is responsible for walkabout disease in stock. New South Wales specimens of this species are much less toxic than material from the vicinity of Fitzroy Crossing and Ewart has suggested that possibly two or more saponins of varying toxicity may be present in varying proportions in material from different localities. The saponin is stable and retains its toxicity for months. Dr. H. W. Bennetts (priv. comm.) has commented on the similarity between the toxic symptoms caused by *A. hemiglauca* and by *Senecio* species. This is of interest since the poisonous principles of the latter are alkaloids.

Acacia Cunninghamii (21), in addition to being cyanogenetic, is of interest in that its unripe pods contain about 3 per cent. of a highly toxic saponin which resembles the mydriatic alkaloids in its properties, producing local anaesthesia, mydriasis and paralysis of accommodation. Hurst (21) also records references to the presence of toxic saponins in *Acacia delibrata* A. Cunn. ex Benth., *A. pulchella* R.Br. and *Dodonaea physocarpa* F. Muell.

The genus *Isotropis* contains some powerfully toxic species, notably *I. atropurpurea* F. Muell. from which Finnemore has isolated a saponin. *I. cuneifolia* (Sm.) Domin. var. *parviflora* Benth. has been proved toxic to sheep and *I. juncea* Turcz. to guinea pigs; there is strong field evidence against *I. cuneifolia* (Sm.) Domin., while *I. Drummondii* Meissn., *I. canescens* F. Muell. and *I. Forrestii* F. Muell. are considered toxic. There is no indication of the nature of the poisonous principles of these species.

Albizzia distachya (Vent.) Macbride is recorded by Maiden (22) as containing about 10 per cent. of saponin in its dried roots, while the blister bush, *Phebalium argenteum,* is considered to be very rich in saponins. *Anagallis arvensis,* the scarlet pimpernel, contains the highly toxic cyclamin in its roots and saponins are also recorded to be present in *Cardiospermum Halicacabum* L. (32), *Tetragonia expansa* Murr. (21) and *Trianthema crystallina* Vahl. (21).

The caustic vine, *Sarcostemma australe* R.Br., is of interest because, although it has been proved toxic to stock and to laboratory test animals (57) in the Eastern States, it is generally regarded as a most useful fodder plant in Western Australia. Finnemore has shown the absence of alkaloids

and prussic acid from eastern material while Earl and his co-workers (58) have isolated a saponin which hydrolyses to give glucose and an aglucone, which in turn gives benzoic and cinnamic acids and the substance sarcostin which is considered to be probably a steroid.

Other indigenous plants known to contain saponins are *Trymalium spathulatum* (Labill.) Ostf. and *Pittosporum phillyreoides*.

(iii) *Other Toxic Glycosides.*

The cape tulips *Homeria collina* Vent. and *H. miniata* Sweet are both toxic, the latter having a digitalis-like action on the heart, constricting blood vessels, raising blood pressure and having a curare-like action on voluntary muscle. Watt and Breyer-Brandwijk (32) record the isolation by Mackenzie of a glycoside from *H. miniata*. but Clarke (59), in stating that the poison occurs in all parts of the plant, considers it to be probably an alkaloid. *Raphanus raphanistrum* L. is an irritant poison to stock when taken in excess and is recorded by Steyn (60) as containing a sinalbin-like glycoside together with the hydrolysing enzyme myrosin. *Plantago major* L. (32) contains aucubin in most parts of the plant. The recorded isolation (61) of carissin, which resembles strophanthin in its action, from the bark of *Carissa ovata* R.Br. is of interest and suggests that *C. lanceolata* R.Br. might be worth investigation.

(b) ALKALOIDS.

Alkaloids are not as widely distributed through the plant kingdom as are members of the preceding groups, but when they do occur, they frequently do so in groups of related substances distributed through plants which are closely related botanically. Thus alkaloids of the berberine type are distributed through many families of the adjacent orders Ranales and Rhoeadales, while individual families like the family Solanaceae are particularly rich in alkaloids, in this case of more than one type.

In the family Solanaceae, the genus *Duboisia* is of outstanding importance. In the Eastern States, *D. myoporoides* R. Br. and *D. Leichhardtii* (F. Muell.) F. Muell. have been fairly recently developed as major sources of hyoscine and hyoscyamine. *D. myoporoides* appears to exist in two physiological forms, in one of which (that which occurs in Queensland and in New South Wales north of Gosford) hyoscine predominates, while in the other, the southern form, hyoscyamine is the principal alkaloid. Hyoscyamine is, however, more readily recovered from *D. Leichhardtii* which contains about 3 per cent. of the alkaloid in its leaves.

D. Hopwoodii, the only species of the genus occurring in Western Australia, has been examined by numerous workers. This plant, the pituri or chewing narcotic of the aborigines, was first examined chemically by Bancroft who showed that the alkaloid it contained was different from that occurring in *D. myoporoides*. Von Mueller, in 1879, concluded that the alkaloid was similar to but not identical with nicotine. The name piturine was given to the alkaloid but it was subsequently shown to give reactions similar to those of nicotine. The identity of the alkaloid appeared to be satisfactorily settled when Rothera in 1910 isolated only nicotine from a specimen of pituri identified by Ewart as consisting of *D. Hopwoodii.* Doubt was cast on the accuracy of this work when it was subsequently learned that, in parts of South Australia at any rate, pituri was not always ob-

tained from *Duboisia* alone and the suggestion was put forward that the material examined by Rothera contained an appreciable amount of dust from the easily powdered leaves of *Nicotiana excelsior* J. M. Black (62). A re-examination of material from South Australia led to the isolation of *d*-nornicotine by Späth (63) with no indication of the presence of nicotine. This material, however, had been wet by heavy rain and had been kept damp for some considerable time, leading to partial racemisation of the nornicotine. It is quite possible that demethylation of any nicotine present may have occurred at the same time.

As part of a programme drawn up by the Drug Panel of the Department of Industrial Development, Dr. D. E. White has carried out some preliminary work on *D. Hopwoodii* from the vicinity of Ajana. He has shown that the principal alkaloid present is nicotine and that nornicotine, if present at all, occurs only in very small amount. Subsequent work on material collected on varying soil types from the vicinity of Canna to a little south of Perenjori has shown that nicotine is always the predominant alkaloid but that occasionally the nornicotine content (calculated on the yield of the picrates) approaches very close to the nicotine content. The repeated statement that *D. Hopwoodii* from the Eastern States contains no nicotine can perhaps only be explained by the existence of physiological forms of the plant. The investigation is being continued.

Further genera of importance in this family are *Anthocercis*, *Anthotroche*, *Datura* and *Nicotiana*. *Anthocercis viscosa* R. Br. contains the oily alkaloid anthocercine (21) and *A. littorea* Labill. has been held responsible for the death of children. This and other species of the same genus, as well as the species of the closely related genus *Anthotroche*, require examination. The introduced *Datura Metel* L., *D. Tatula* L. and *D. Stramonium* L. have been thoroughly investigated in other parts of the world and Finnemore has examined Australian grown material. *D. Metel* has been shown to contain chiefly hyoscine with a little atropine or hyoscyamine and norhyoscyamine, *D. Stramonium* to contain hyoscyamine in the leaves and seeds and both hyoscyamine and hyoscine in the roots, while *D. Tatula* contains hyoscyamine and atropine. The maximum amounts of alkaloids recorded do not differ materially from the maxima recorded for Britain and elsewhere. *D. Leichhardtii* F. Muell. has not been examined in Western Australia.

Nicotiana glauca Grah. has been investigated by many workers and has until recently been considered to contain only nicotine to the extent of something less than one per cent. Quite recently, Smith and Smith (64) have shown that anabasine makes up about 97 per cent. of a total of little more than 0.6 per cent. of alkaloids and that nicotine is present only in very small amount. *N. suaveolens* Lehm. was recognised by Staiger in 1886 as containing a volatile alkaloid which resembled nicotine. This alkaloid was considered to be the toxic principle of the plant until Smith and Smith (*loc. cit.*) showed it to contain both nicotine and nornicotine, the latter making up about 65 per cent. of a total of less than 0.5 per cent. of alkaloids. *N. excelsior* does not appear to have been examined chemically. It is used by the aborigines, as is *Duboisia Hopwoodii*, as an emu and kangaroo poison, and Hicks (62) records its use as a chewing narcotic.

The genus *Solanum* is the largest of the family Solanaceae in Western Australia. Many of its members contains the high molecular weight alkaloids of the glycosidic steroid type such as solasonine (solanine-s), and are therefore more or less toxic. *S. chenopodinum* F. Muell. (21), *S. nig-*

rum L. (32) and *S. sodomaeum* L. (65) are all recorded as containing solasonine or "solanine" and, in addition, *S. nigrum* is said to contain a tropine alkaloid which possesses mydriatic properties. *S. Sturtianum* F. Muell. is also recorded (21) as being markedly toxic to sheep and probably containing "solanine".

The order Leguminosae is very well represented in the Western Australian flora and, in the world as a whole, it provides more substances of medicinal importance than any other order. In the family Papilionaceae, *Crotalaria retusa* L. has been shown (66) to contain the alkaloid monocrotaline. This is of considerable interest because it establishes a relationship with the senecio alkaloids, since on boiling with barium hydroxide solution it gives retronecine as one of its decomposition products. *C. dissitiflora* Benth. has been found by Finnemore to contain an alkaloid and *C. Mitchelli* Benth., which is suspected of being poisonous, might well contain alkaloids. *Indigofera boviperda* A. Morrison has been proved toxic to cattle in Northern Australia and is suspected of containing alkaloids (67); *I. australis* has also been recorded as a stock poison.

The presence of alkaloids in the genera *Gastrolobium* and *Oxylobium*, which include perhaps the most toxic of Western Australian plants, was indicated by the work of Mann and Ince (68) who described the isolation of cygnine and lobine respectively from *G. calycinum* Benth. and *O. parviflorum* Benth. This has not been confirmed by other workers, but it has very recently received support to some extent by the demonstration by Dr. D. E. White of the presence of alkaloids in *O. graniticum* S. Moore. The solution of the problem has been simplified by Dr. H. W. Bennetts (69) who has demonstrated that all the toxic members of the two genera produce the same series of symptoms provided the dose is modified according to the general toxicity of each individual plant. Further general information on these species is contained in references (69) to (73) inclusive.

Introduced plants in the family Papilionaceae include *Cytisus prolifer* L. and *Ulex europaeus* L., both of which contain cytisine, while among the *Lupini*, *Lupinus angustifolius* L. contains *d*-lupanine and *L. luteus* L. contains lupinine and sparteine as well as a glucoside. *L. hirsutus* L. is considered toxic in South Africa and is probably alkaloidal in nature.

The family Caesalpiniaceae is also known to contain alkaloids. *Erythrophleum chlorostachys* (F. Muell.) Hennings ex Taub., one of the so-called camel poisons, is exceedingly poisonous to most stock. Petrie and Priestly (74) have shown the absence of saponins and cyanogenetic glycosides in the plant and have isolated an alkaloid from it which has identical chemical and physiological properties to erythrophleine. *Caesalpinia Bonducella* (L.) Fleming is recorded (32) as containing an alkaloid in its seed and, in addition, it contains a bitter principle, bonducin, which is stated to be as effective as quinine in treatment of malaria.

The family Compositae is the largest in the plant kingdom and a number of its members contain alkaloids. Within recent years much work has been done, particularly in South Africa and Canada, on the alkaloids of the genus *Senecio*. This work has been reviewed by Waal (75), while more recent work has been published by the same author (76) and by Richardson and Warren (77). The introduced *S. vulgaris* L. contains senecionine and senecine and is known to produce the typical symptoms of senecio poisoning, including cirrhosis of the liver. *S. lautus* Soland. is stated by Bennetts

(78) to be toxic and to have selective action on the liver, although subsequently the feeding of half a pound of the plant daily to each of two sheep for eight weeks failed to produce any evidence of liver cirrhosis (Bennetts, priv. comm.). Species of the closely related genus *Erechthites* are also known to contain similar alkaloids. In the same family, *Xanthium spinosum* L. is recorded (21) as containing an alkaloid with an intense action on the central nervous system, while *Brachycome graminea* (Cass.) F. Muell. has given doubtful positive reactions for alkaloids. The genus *Eclipta* is of interest since the Indian species *E. alba* Hassk. has been shown (79) to contain nicotine.

The seeds of *Strychnos lucida* R. Br. have been examined in New South Wales (21) and material from Kunmunya Mission in the Kimberleys has been shown (80) to contain both strychnine (about 0·8 per cent.) and brucine (about 1.5 per cent.). *Dodonaea viscosa* is recorded (32) as being used as a fish poison and to contain an alkaloid which has stimulant properties similar to those of coca. *Tetragonia expansa* has been found by Finnemore (21) to contain alkaloids in addition to the saponin already mentioned. *Crinum asiaticum* L. contains lycorine which is fairly widely distributed in the family Amaryllidaceae.

Among introduced plants, the chemistry of the alkaloids of the spotted hemlock, *Conium maculatum* L., has been thoroughly worked out. *Lolium temulentum* L. often contains a poisonous fungus (*Endoconidium temulentum*) in its seeds from which the alkaloid temuline was isolated by Hofmeister in 1892. The grass has been recorded by Carne and Gardner (81) as producing intoxication, particularly in pigs. The same fungus is believed to occur in rye grass, *L. perenne*. *Lithospermum arvense* L. contains the alkaloid cynoglossine which has a curare-like action, and possibly consolidine with which it is often associated. The cape lilac, *Melia azedarach* L., has been stated (82) to contain azaridine in its fruits. The alkaloid mesembrine has been isolated (83) from *Cryptophytum crystallinum* (L.) N. E. Brown and from more than twenty other species of this and related genera of the *Mesembryeae*. It resembles cocaine in its action but its local anaesthetic properties are much weaker. *Vicia sativa* contains the purine alkaloids vicine, convicine and vernine, the latter also being present in *Trifolium pratense* L. *Brassica nigra* (L.) Koch. contains sinapine in its seeds. In the family Papaveraceae, the introduced poppy, *Papaver hybridum* L. contains alkaloids and the Mexican poppy, *Argemone mexicana* L., contains berberine and protopine, but in neither of these, nor in *P. aculeatum* Thunb., is morphine present.

Among indigenous plants which suggest themselves for examination for alkaloids is a big group in the order Contortae from the families Apocynaceae and Asclepiadaceae. In particular, the genera *Alstonia*, *Wrightia*, *Asclepias*, *Cynanchum*, *Tylophora* and *Marsdenia*, of which numerous species are known to contain alkaloids, should be investigated. Of equal importance is the genus *Lobelia* and possibly *Isotoma* while other species worth consideration are *Erythrina vespertilio* Benth., *Sarcocephalus coadunatus* (Sm.) Druce and possibly *Dioscorea hastifolia* Endl. and *Salsola Kali* L.

(c) PLANTS CONTAINING NITRATES.

The presence of nitrites in plants can give rise to toxic symptoms in animals through the conversion of haemoglobin into methaemoglobin, so interfering with the oxygen carrying capacity of the blood. Nitrates,

through enzymic reduction, are capable of producing the same effects. *Tribulus terrestris* L. has been shown in South Africa (84) to contain a little nitrite and an appreciable amount of nitrate, and its poisoning symptoms are those of acute asphyxia. The spotted thistle, *Silybum Marianum* (L.) Gaertn., has been known to contain up to 25 per cent. of potassium nitrate, calculated on a dry basis, and its toxicity is almost certainly due to the reduction of this nitrate to nitrite with the resultant conversion of haemoglobin into methaemoglobin. It seems possible that the toxicity of *Cynodon Dactylon* may be due in part to a similar cause, and the possibility may be extended to *Erythrina vespertilio* since some species of this genus are known to contain nitrites.

(d) Photosensitising Plants.

Photosensitisation of stock does not seem to be of the same importance in this State as it does in South Africa or in the Eastern States and New Zealand. Steyn and van der Walt (85) have shown that *Lantana Camara* L. is toxic and produces photosensitisation, while Louw (86) has isolated lantanin from the plant and established it as the photosensitising agent. Steyn and van der Walt (*loc. cit.*) also record the isolation of a trace of an alkaloid from *L. crocea* Jacq. which produced the characteristic symptoms of poisoning by this plant. Quin and Rimington have shown in South Africa that the photosensitising action of *Medicago denticulata* Willd. is due to the production of phylloerythrin from chlorophyll in the rumen of the animal either by bacterial or protozoan activity. The effect produced by *Tribulus terrestris* is attributed to the same cause and both *Medicago minima* (L.) Grufb. and *Chloris truncata* are similarly suspected. It should be noted, however, that the photosensitising action of St. John's wort, *Hypericum perforatum* L. var. *angustifolium* DC., is due to the presence of a mixture of closely related pigments, called hypericin, which in very low concentration produces haemolysis on exposure to light of suitable wave length (21; 87). *Panicum effusum* R.Br. (21; 60) is also photosensitising, but no work appears to have been published on the chemical aspect of this action. *Trifolium hybridum* L. and *T. pratense* are both recorded by Steyn (60) as producing photosensitisation.

(e) Fish Poisons.

Fish poisons have been used for centuries by natives in different parts of the world and many such materials from Central and South America, tropical Africa, India, Malaya, the East Indies and the Pacific Islands have been examined systematically by numerous workers to determine their insecticidal value. Through the influence of the paleotropic flora on Australian vegetation, an influence which extended down the eastern portion of Africa, it is reasonable to expect that fish poisons similar to those found in Indo-Melanesia and East Africa will be found among our own northern and north-western flora.

No species of the outstanding genera *Derris* and *Lonchocarpus* are known in this State, but several genera which are known to contain the same active principles as *Derris* do occur in the North-West and Kimberleys. Thus some species of *Tephrosia* have considerable local use as insecticides in other parts of the world although they are admittedly not as effective as *Derris*. In Western Australia there are sixteen species of *Tephrosia*, of

which two, *T. purpurea* Pers. and *T. rosea* F. Muell. ex Benth., are known to be poisonous. These two species at least should be investigated for their insecticidal value. In the same category is the genus *Barringtonia* and possibly the genus *Terminalia*.

The bark of *Careya australis* F. Muell. is used as a fish poison in Queensland and Northern Australia and material from Arnhem Land has been examined (88) for insecticidal properties but found to be without toxic effects on *Aphis rumicis*. The bark of *Acacia salicina* is recorded by Hurst (21) as being used as a fish poison.

(f) MISCELLANEOUS POISONS.

Abrus precatorius L. contains two toxic proteins, a paraglobulin and a phytalbumose, the mixture being known as abrin. Abrin is not necessarily poisonous when taken orally but it is highly toxic when injected. It has been used therapeutically in treatment of opacity of the cornea and granulation of the eyelids, but the inflammation it produces is dangerous and sometimes difficult to control. The introduced *Cucumis myriocarpus* Naud. has frequently been reported toxic to stock and human beings. Finnemore has shown the absence of prussic acid and South African workers have separated several toxic materials from the fruit. Quin isolated in 1928 a non-alkaloidal, non-glycosidal substance which was highly toxic to animals, whether given orally or by injection. In 1933 Rimington separated the amorphous very toxic substance cucumin from this and other species of *Cucumis*. Subsequently Rimington and Steyn (89) isolated the apparently pure compound $C_{28}H_{42}O_8$ and showed that it was probably a dilactone. *Pteridium aquilinum* (L.) Kuhn., the bracken, which is toxic to cattle and horses, is stated by Steyn (60) to contain pteritannic acid (identical with filicic acid from *Dryopteris Filix-mas*) as its main active principle.

Leonotus leonurus R. Br., which is smoked by natives in South Africa like Indian hemp and which produces a similar stupefying effect, is recorded by Watt and Breyer-Brandwijk (32) as containing a dark green resin which is probably responsible for the narcotic action. The same authors also refer to the separation of two phenolic substances from the reddish leaf oil. The prolonged blood-clotting time associated with the eating of *Melilotus alba* Desr. and probably *M. indica* All., is discussed by Hurst (21). The presence of coumarin has been shown to have a bearing on the ability of the clover to become toxic and a specific substance has been isolated from spoiled clover which inhibits blood-clotting.

Oxalic acid and oxalates are widely distributed in the plant kingdom, often in sufficient quantity to cause stock poisoning. Many species of *Rumex* and *Oxalis*, for example, contain enough to produce poisoning if eaten to excess and *Salsola Kali* is known to contain a considerable amount of the acid.

There are many plants which have been proved toxic but no information is available concerning their active principles. In some cases, a knowledge of the poisonous constituents of other species belonging to the same or to related genera may be of value as a guide, but in others there is little evidence to suggest possible lines of attack. Amongst the more important of these plants are *Anagallis femina* Mill., *Bryonopsis laciniosa*, *Cryptandra leucophracta* Schlecht., *Didiscus glaucifolius* F. Muell. (which contains

neither alkaloids nor prussic acid), *Echinopogon* spp., *Malva parviflora* L., *Mimulus repens* R. Br., *Morgania glabra* R. Br., *Myoporum acuminatum* R. Br., *M. deserti, Pimelia flava* R. Br., *P. trichostachya* Lindl., *Sinapis arvenis* L., *Solanum ellipticum* R. Br., *Trema amboinensis, Velleia discophora* F. Muell. *V. panduriformis* A. Cunn., *Wedelia asperrima* (Dene) Benth., *Wikstroemia indica* (L.) C. A. May, *Zantedeschia aethiopica* Spreng. and *Zornia diphylla* Pers. Acrid, blistering and emetic latexes are produced by many members of the family Euphorbiaceae, including *Excaecaria Agallocha* L., *E. parviflora* Muell. Arg. and *Euphorbia Peplus* L.

Among the more important plants which are suspected poisons, but concerning which little definite information is available, the following are perhaps the most noteworthy:—*Acacia armata* R. Br., *Beyeria viscosa* (Labill.) Miq., *Carduus pycnocephalus* L., *Centaurea melitensis* L., *Centipeda minima* (L.) A. Braun et Aschers, *Didiscus pilosus* Benth., *Epaltes australis* Less., *Eremophila glabra* (R. Br.) Ostf., *E. Latrobei* F. Muell., *E. Sturtii* R. Br., *Goodenia glauca* F. Muell., *Gyrostemon Sheathii* W. V. Fitzg., *Inula graveolens* Desf. (32), *Lactuca saligna* L., *L. scariola* L., *Lavatera plebeia* Sims, *Microseris scapigera* (Forst. f.) Schultz et Bip. and *Ranunculus lappaceus* Sm.

VI.—DYES AND COLOURING MATTERS.

The greater part of the work which has been done on Western Australian plant colouring matters is unpublished work by Dr. D. E. White, who has kindly made available the following information. *Anigozanthos flavida* Red. contains cyanidin pentose glycoside; *A. Manglesii* D. Don, anthocyanin, possibly conjugated with tannin; *Boronia megastigma,* delphinidin pentose glycoside, partially methylated, together with some disaccharide; *Chamaelaucium uncinatum,* malvidin dimonoside; *Chorizema cordatum* Lindl., malvidin monoside; *Eucalyptus ficifolia* F. Muell., pelargonidin together with some cyanidin bioside; *Oxylobium lanceolatum* (Vent.) Druce, malvidin monoside. *Clianthus speciosus* (G. Don) Aschers et Graebn. from South Australia contains pelargonidin monoside in the red portion of the flower and cyanidin monoside in the black, while the partial white variant from western New South Wales contains peonidin monoside in the keel and pelargonidin monoside in the standard.

Maiden (22) records the presence of a red colouring matter, which is very sensitive to acids and alkalies, in the juice of the fruit of *Eugenia australis* Wendl., and Herbert (90) records similar colour changes with the flowers of several species of *Eriostemon* and *Boronia*. This is particularly noticeable in the case of *B. tenuis* (Lindl.) Benth., in which carbon dioxide in a moist atmosphere will change the colour from blue to pink.

Little is known concerning the colouring matters or dyes which occur in woods and barks. The yellow pigments of jam wood (*Acacia acuminata* Benth.) are referred to in the next section on vitamins, and Maiden (22) mentions the presence of a yellow dye in the bark of *A. subcaerulea* Lindl. A strong yellow colouring matter is also present in the wood of *Sarcocephalus coadunatus*. The wood of *Caesalpinia Bonducella* contains, as does that of many other species of the genus, the substance brasilin and its red oxidation product brasilien. Woods of this nature, like sappan and logwood, have long been used for dyeing.

VII.—VITAMINS.

Very little work has been done on the vitamin content of indigenous or introduced plants in Western Australia. Maiden (22) records that *Trigonella suavissima* Lindl. is an excellent antiscorbutic and that *Portulaca oleracea* L. is used for the same purpose and is apparently highly nutritious. *Rumex Acetosella* L. has been used in treatment of scurvy (32) but it may produce oxalic acid poisoning if eaten to excess. Hill (91) has determined the ascorbic acid content of various cultivated fruits and has obtained evidence of the presence of carotene in the petroleum ether extract of *Acacia acuminata* wood (92). This was confirmed by Trikojus and Drummond (93) who isolated pure β-carotene from the extract and obtained evidence of the presence of five other carotinoid pigments. These five fractions were examined spectroscopically but they were not pure enough for differentiation and identification. Underwood and Conochie (94) have determined the carotene content of a number of pasture species, some of which are indigenous.

VIII.—MEDICINAL SUBSTANCES.

A number of products which are or could possibly be used in medicine have already been referred to in their appropriate sections, notably eucalyptus and sandalwood oils, the seeds of *Strychnos lucida* and the *Alstoniae*. There are, however, a few which have been used medicinally, some of which appear to warrant vigorous exploitation, and many which require both chemical and physiological examination. *Euphorbia pilulifera* L., a tropical herb of wide distribution, is used in treatment of bronchitis and asthma. *Agropyron repens* (L.) Beauv. is used as a demulcent diuretic, and wattle bark and eucalyptus kino are employed as astringents.

Of some considerable importance are plants which are known to be of value in treatment of diarrhoea and dysentery. Outstanding among these is *Grewia polygama* Roxb., although it is not known whether it simply checks diarrhoea or will cure bacillary or amoebic dysentery. *Alyxia buxifolia* has already been mentioned in this respect, and the following are also used either in South Africa, India or Australia for the same purpose:—*Bidens bipinnata* L., *Erodium moschatum* (L.) L'Her., *Euphorbia alsinaeflora* Baill., *Evolvulus alsinoides* L. and *Melastoma malabathricum* L.

Bitter substances find considerable use in tonics and much dandelion root is normally imported, as well as many other drugs, for this purpose. There are, however, many bitters available in the State and there should be little necessity to import such substances. *Strychnos lucida* has already been mentioned and there are many members of the family Gentianaceae which might be profitably exploited. Among these are *Erythraea australis* R. Br., *Sebaea ovata* (Labill.) R. Br. and *Villarsia* spp. Additional bitters which might be employed are the *Alstoniae*, *Petalostigma sericea* (R. Br.) C. A. Gardn., *Marrubium vulgare* L. and *Codonocarpus cotonifolius* F. Muell.

Many *Cassiae* contain emodins and resins and consequently act as purgatives. The leaves of *C. Sophera* L. are used as a substitute for senna in some parts of India and the related Western Australian *Cassiae*, particularly *C. pleurocarpa* F. Muell., should be examined for similar properties. Other plants which have been used as purgatives are *Gratiola pedunculata* R. Br. and *G. peruviana* L., while the intensely bitter Afghan melon, *Citrullus vulgaris* Schrad., is almost certain to be a drastic purgative.

Extracts of *Erodium cicutarium* (L.) L'Her., which have a powerful effect on the uterus, resulting in an increase of contractile activity, have been used in Europe for arresting uterine haemorrhage. No compound with these properties has yet been isolated from the plant. Somewhat similar properties are possessed by *Adiantum aethiopicum* L., extracts of which are used by the Sutos for promoting parturition, and by *Pteridium aquilinum* which is used, along with the bulb of *Vernonia corymbosa*, as an abortifacient.

Diuretic properties are possessed by *Boerhaavia diffusa* L., *Indigofera enneaphylla* L. and *Trichodesma zeylanicum* (Burm. f.) R. Br., while the roots of *Hybanthus enneaspermus* (L.) F. Muell. are used in India for treatment of diseases of the urinary tract. *Plumbago zeylanica* L. and *Siegsbeckia orientalis* L. are recorded as powerful sudorifics, and *Erodium moschatum* also possesses diaphoretic and antipyretic properties.

Thespesia populnea (L.) Soland. ex Corr. is used for treatment of skin parasites and scabies in India, and in South Africa *Cassytha filiformis* L. is used to eliminate head vermin. *Hibiscus trionum* L. is employed as a remedy for round worms and the use of *Cheilanthes hirta* for the treatment of tape worm suggests that the local representatives of the genus should be examined. *Hydrocotyle asiatica* L. is listed by Hurst (21) as having a multiplicity of medicinal uses a few of which would appear to need some justification. *Cassia mimosoides* L. appears to possess sedative properties and it is used, in much the same way as hops, as a pillow, or under a mattress, to induce sleep. *Clematis microphylla* DC. contains irritant substances and may be used as a counter-irritant in the form of poultices. Reference has already been made to the quick healing properties of the oleo-resin in the fruit of *Actinostrobus glaucus*; similar properties are possessed by the leaves of *Cymbonotus Lawsonianus* Gaud., which, when extracted with lard, give a useful salve for dressing wounds.

Some lines of investigation which might lead to the recognition of useful medicinal plants have already been indicated. Others include the examination of the genus *Polygala* from which senega is obtained, the genus *Goodenia*, some species of which are used by gins for making children sleep on long journeys, the genus *Haemodorum*, some species of which are used by natives as purgatives, and likely members of the order Rhamnaceae, which might possess barks resembling cascara, and of the order Rubiaceae, many of which contain valuable alkaloids.

IX. WOOD DISTILLATION.

This review would not be complete without some reference to work which has been done on wood distillation. Almond, Holmes and Plant (95) have prepared and examined charcoals from dry and green saplings and mature trees of *Eucalyptus marginata* and from *E. redunca* var. *elata*, *E. salmonophloia* and *E. salubris*. They have also described (*loc. cit.*), charcoals prepared from *E. rostrata* Schlecht. from Victoria and New South Wales and from *E. alba* from Queensland. It is possible that the latter is identical with *E. platyphylla* F. Muell. The report of the Mines Department for 1940 contains proximate analyses of specimens of charcoal, obtained from local charcoal burners, prepared from *E. calophylla*, *E. marginata* and *E. redunca* var. *elata*. Gregson (96), in discussing some aspects of the use of charcoal as a fuel in gas producers, has given the results of the analysis of a number

of samples of charcoal from *E. marginata* as well as calorific values for charcoal obtained from *E. calophylla, E. redunca* var. *elata,* "mulga" and "ti tree."

N. A. Hanley and J. F. Pearse have investigated, for the Iron and Steel Panel of the Department of Industrial Development, the distillation of the wood of *Eucalyptus calophylla, E. diversicolor, E. marginata* and *E. redunca* var. *elata,* as part of the preliminary work in connection with the establishment of a pilot plant for the production of charcoal iron at Wundowie. An examination was made of the composition of the liquid distillate and of the wood gas at varying temperatures and the relationship of the volatile content of the charcoal to the retorting temperature was studied in the case of *E. marginata.* It was found that *E. calophylla* gave the highest yields of methyl alcohol and acetic acid and that, while the yields of acetic acid were only slightly lower with *E. diversicolor* and *E. redunca* var. *elata,* these two species gave considerably less methyl alcohol. *E. marginata* gave much lower yields of both products. The results obtained from *E. calophylla* compared reasonably well with those from such North American hardwoods as beech and maple. From the point of view of charcoal production, highest yields were obtained from *E. marginata* and *E. redunca* var. *elata.*

X. CONCLUSION.

It should be clear from what has been said that there is an immense field open for the study of the native plants of this State, a field commanding the attention not only of chemists, but of botanists, agriculturalists, entomologists, pastoralists and manufacturers. There is no institution here in which pharmacological work is being carried out and there appears to be no one interested in ethnological aspects of our native tribes which might have bearing on some of the problems which have been indicated. Such facilities as do exist for chemical investigations are limited to a greater or lesser extent by the nature of the other work which must be performed in the institutions which enjoy these facilities. In consequence it is felt that too strong a plea cannot be made for the establishment of either a separate Government department or a branch of an existing department, a principal function of which would be the investigation of these problems. A start in a very small way has been made by the Department of Industrial Development in the establishment of a Drug Panel, but on its present footing this panel can contribute very little towards the solution of some of the major problems which have been indicated and which may take several years to solve. An appreciation of the results of the fruitful association of botanist and chemist as represented by the joint work of Baker and Smith and of the continued flow of valuable work from the Sydney Technological Museum, carries with it the conviction that we are neglecting a field of enquiry which must ultimately adequately repay any capital expenditure on buildings and equipment as well as salaries paid to new officers.

Essential requirements for such a new department or branch would include adequate housing of the State herbarium which should be extended to feature all products of possible technical importance, and the provision, preferably in the same building, of the necessary laboratory accommodation and equipment for carrying out the chemical investigations. Ground or floor space for small pilot plant investigations is also essential, as well as adequate space for gardens for cultivation and breeding experiments.

Until such provisions are made, our chemical knowledge of Western Australian flora must wait on such progress as can be made from our existing institutions, or on the activities of private firms which are naturally interested only in those plants which offer some prospect of immediate profitable exploitation.

In conclusion I should like to express my great appreciation and indebtedness to Mr. C. A. Gardner for the generous assistance he has given in establishing the names of the species mentioned in this address.

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